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NASA Turbulence Technologies In-Service Evaluation: Delta Air Lines Report-Out

Christian Amaral, Captain Steve Dickson, and Bill Watts
Delta Air Lines, Inc.
Atlanta, Georgia

Under NASA Contract NND06AE46P

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1 Overview

1.1 Executive Summary

Concluding an in-service evaluation of two new turbulence detection technologies developed in the Turbulence Prediction and Warning Systems (TPAWS) element of the NASA Aviation Safety and Security Program's Weather Accident Prevention Project (WxAP), this report documents Delta's experience working with the technologies, feedback gained from pilots and dispatchers concerning current turbulence techniques and procedures, and Delta's recommendations regarding directions for further efforts by the research community.

Technologies evaluated included an automatic airborne turbulence encounter reporting technology called the Turbulence Auto PIREP System (TAPS), and a significant enhancement to the ability of modern airborne weather radars to predict and display turbulence of operational significance, called E-Turb radar.

The in-service evaluation validated the two technologies as enablers for aviation safety improvements, and revealed to Delta the negative impact of turbulence on airspace capacity, airline economics, and environmental concerns. Representing a subset of weather constraints affecting airspace utilization and responsible for excessive fuel burn and emissions, lack of high quality, comprehensive information on turbulence stands as a significant challenge facing the Next Generation Air Traffic System (NGATS). The use of better data as result of improved detection technologies is therefore seen as a key enabler to increasing the safety of flight, easing airspace restrictions, and reducing the environmental impacts of air travel, forming the basis for the recommendations that follow in Section 5.

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1.3 Background

The problem of turbulence has long plagued the aviation business. Relying on what has historically amounted to a very sparse dataset of winds, temperatures and pilot reports (PIREPs) to populate forecasts and warnings, it now stands as the last major weather-related safety challenge facing large commercial aircraft.[1] Turbulence is the leading cause of passenger and crew injuries today, resulting in $26 million in related annual expenses to US airlines.[2] However, the economic consequences of turbulence that are not related to safety are perhaps even more startling. A study conducted by the Volpe National Transportation Systems Center initially calculated that the annual cost to US airlines of airframe inspections, delays, cancellations and diversions due to turbulence exceeded $750 million,[3] although a subsequent analysis put these costs at about $100 million. In addition, because users lack good tools to define these hazards, other costs due to the conscientious but probably overly conservative avoidance of turbulence could be even higher, and receive major attention later in this document.

Following a series of flight experiments demonstrating the fundamental technical success of TAPS and E-Turb radar on the NASA B-757 research aircraft, NASA approached Delta Air Lines in late 2003, proposing an in-service evaluation of these technologies. While further demonstrating the technical performance of the two technologies, the need for aviation operational experience with these concepts was needed. Focusing on TAPS and E-Turb radar as technologies to reduce injuries related to turbulence as a goal of the WxAP program, the in-service evaluation was underway with Delta participation in early 2004. Additionally, the TPAWS development partners were granted open access to the airline's operational personnel.

Although this report does discuss some of the high level technical results obtained from the in-service evaluation, the official source for technical results and descriptions can be found in the proceedings of the 5th annual NASA WxAP Review held at Williamsburg, Virginia in September of 2005.

Through January of 2006, the technical merits of both systems were further validated, and as documented in Appendices C and D of this report, Delta dispatchers and pilots provided valuable operational feedback regarding both technologies.

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[1] August 2003 National Aviation Weather Program Mid-Course Assessment. This analysis delineated weather-related risks facing various segments of the aviation marketplace (general aviation, business aviation, air taxi, air carriers etc.).
[2] B. Campbell and S. Borener, US DOT/Volpe Center, Cambridge, MA, AIAA-2004-6395. AIAA 4th Aviation Technology, Integration and Operations (ATIO) Forum, Chicago, Illinois, September 2004
[3] Ibid.

1.4 Technology Description

Using the existing sensors on most modern commercial airliners, the Turbulence Auto PIREP System (TAPS) is an event driven turbulence encounter reporting mechanism that uses airborne "g" load measurements to indicate the aircraft severity response. Upon encountering a turbulence incident that exceeds a pre-determined acceleration threshold, a report of the aircraft response, in rms "g," is automatically downlinked to a groundstation for dissemination among various user groups. Compared to current voice reports of turbulence by pilots, TAPS has the advantage of providing more turbulence reporting data in a more accurate and timely manner. Also, since TAPS reports include real time information on the peak "g" loads that were encountered, maintenance personnel can use TAPS to assist in determining the necessity and complexity of airframe inspections following turbulence encounters.

Minimizing the datalink expenses associated with TAPS reports was viewed as an important element of the in-service evaluation. Therefore, the minimum threshold for reports to be generated was approximately .1 rms "g." The technical performance of the TAPS algorithm was also perceived by developers to be degraded any time that flaps were deployed, which typically occurs below 10,000 feet MSL. Given these considerations and the fact that passengers are usually seated with their seatbelts fastened below 10,000 feet, reports were inhibited from being generated below 9500 feet above Mean Sea Level (MSL).

Although current generation airborne weather radar units have a function whereby particulate-based turbulence can be presented in the color magenta over radar echoes, for a number of reasons, the system rarely presents accurate, reliable information. The E-Turb radar is a major enhancement which predicts an aircraft's hazard response to atmospheric attributes detected by weather radar and displays the severity level and location. This technology a was prototype implemented in a Rockwell Collins WXR-2100 Multiscan radar unit, which includes capabilities such as automatic tilt, ground clutter suppression, and automatic gain compensation. This automation proved critical to the functionality of the E-Turb during the in-service evaluation.

In order to present information on turbulence resulting in degraded ride quality as well as turbulence constituting a potential hazard, the E-Turb technology is capable of displaying two levels of turbulence intensity in the standard color magenta. E-Turb software inputs specific aircraft flight parameters, including weight, to determine the aircraft's predicted response, and has an operational range of about 25 nautical miles ahead of the aircraft. The lower threshold of turbulence, representing turbulence predicted to result in an aircraft response of at least .09 rms "g" but less than .15 rms "g" (representing a change in vertical "g" of approximately .2 to .4), was presented on the display as a pattern of speckled magenta, while all turbulence predicted to result in an aircraft response greater

than or equal to .15 rms "g" (a change in vertical "g" of about .4 or greater) was presented as solid magenta.

While .15 rms "g" was decided as the threshold for solid magenta, this does not represent a level of turbulence that is necessarily hazardous. Rather, setting the threshold at this level captured more data to observe operational responses as part of the in-service evaluation. In guidance to crews, solid magenta was described as advisory information representing turbulence of moderate or greater intensity.

It is important to note that both technologies use the rms "g" quantity to determine and report turbulence hazard severity, making the technologies consistent for aircraft responses to turbulence.

1.5 TAPS Evaluation: History and Overview

Beginning in early 2004, project personnel worked extensively with Delta dispatchers and meteorologists to refine display and functionality requirements for a web-based display of real time TAPS reports that could be presented at these groups' workstations. During the summer of 2004, all 71 of Delta's Boeing 737-800 aircraft were outfitted with the TAPS software, and began transmitting TAPS reports to groundstations based on rms "g" threshold exceedances. A web based flight following product was first utilized as the platform for selected dispatchers to begin viewing graphical TAPS data. This "beta version" of the display provided a real-time feed of TAPS information, and those dispatchers viewing the data gave feedback on their likes and dislikes to help fine tune the display.

In 2005, all 21 of Delta's 767-400ER aircraft, as well as 31 of its Boeing 767-300ERs, were outfitted with TAPS. Additionally, the ability to automatically uplink TAPS data to other equipped aircraft was demonstrated in these later iterations of the TAPS software. These uplinks were transparent to ground-based users and flight crews, and technical success was demonstrated.

Given the scarcity of conventional PIREPs and just some minor criticisms concerning the WebASD display, reactions to the information provided by TAPS were so positive that those dispatchers looking at WebASD began requesting that it be deployed among the entire dispatch group. The project team therefore decided to make a newly refined display of TAPS on WebASD available to all 135 dispatchers. In addition, a 30-minute segment introducing the group to TAPS was incorporated as part of recurrent training for all dispatchers throughout the summer of 2005. Also, by August 31, 2005, more than 35,000 TAPS reports had been made by more than 15,000 Delta flights.[4]

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[4] Robinson, Paul A. "Turbulence Auto PIREP System In-Service Evaluation," NASA's 5th WxAP Review, September, 2005.

Dispatchers continued to use and give qualitative feedback regarding the technology through the conclusion of the program in January of 2006. It is important to note that the information in Appendix C documents only those uses of TAPS data between 1 June 2005 and 31 January 2006 of which Delta project personnel were aware, and is therefore not necessarily comprehensive. Nevertheless, given frequent visits to the Operations Control Center by project personnel and dialogue with various members of the dispatch group, it represents a highly accurate overall picture of the extent to which TAPS was used.

1.6 E-Turb Radar Evaluation: History and Overview

In March of 2004, a Rockwell Collins Multiscan WXR-2100 radar unit was installed on one Delta Boeing 737-800 as the platform for the E-Turb radar enhancement. A Delta Flight Crew Bulletin was issued to all 737-800 pilots in advance of the installation, and crews became familiar with the automated functionality of the unit over an approximately 5-month period. The E-Turb radar was certified and installed as a software enhancement in August of 2004. Another Flight Crew Bulletin explaining the E-Turb functionality had also been drafted and issued prior to its installation, and an onboard supplement was written for further reference by flight crews on the aircraft.

As evaluations got underway, system performance – both quantitative and qualitative – was gauged by a variety of methods. The Multiscan radar transceiver incorporated a data logger that automatically recorded the radar picture presented to flight crews any time the radar detected and displayed levels of E-Turb magenta. In addition, whenever the weather + turbulence mode on the radar was selected by the flight crew (regardless of the presence of E-Turb magenta levels), the data logger recorded the g loads that the airplane encountered for comparison against a recorded radar picture, which aided tremendously in evaluating quantitative system performance. Pilots could also opt to record encounters with weather that they deemed worthy of analysis by the project team. All recordings were periodically downloaded for analysis. Results proved impressive, and are summarized in a histogram that appears in Section 3.

Qualitative feedback on the performance of both the Multiscan radar and E-Turb magenta was solicited via paper questionnaires on the flight deck, ACARS messages, jumpseat observations by personnel assigned to the project, and direct contact via phone and email correspondence with Delta's representatives at company headquarters. These results, which are overwhelmingly positive, are documented in detail as Appendix D.

1.7 Evaluation Elements and Questionnaire Methodology

Throughout the various phases of deploying TAPS on WebASD among dispatchers, Delta project personnel obtained general feedback concerning the

system, as well as documentation of times when TAPS data were used within the operation through frequent visits to the Delta Operations Control Center (OCC). Data in Appendix C log all discussion that project personnel had with dispatchers and meteorologists concerning the system, all known inquiries from pilots regarding TAPS data, as well as all known uses of TAPS between June of 2005 and January of 2006. Because TAPS was not integrated into the applications most referenced by dispatchers, uses of the system usually led to the involvement of project personnel. An explicit request was also made that users make project personnel aware of any times when TAPS was used operationally. So although it was impossible to capture *all* uses of TAPS among 135 dispatchers, what is documented would seem to approach a comprehensive account. Of particular interest in Appendix C are a few applications of TAPS data in some higher profile turbulence encounters that resulted in airframe inspections and injuries.

Qualitative feedback concerning uses of E-Turb radar that occurred during the in-service evaluation is captured in Appendix D. Contents in this section catalogue all input concerning the performance of the Multiscan radar, and subsequently the combined performance of the Multiscan and E-Turb magenta for all entries after 8/21/04. Each entry represents input captured via (1) hard copy questionnaires that were available on the flight deck and mailed to project personnel, (2) phone conversations with pilots who used the radar during encounters with convective weather, (3) detailed observations by project personnel occupying the jumpseat, and (4) information regarding system performance that was sent via ACARS for review by project personnel.

1.7.1 Questionnaire Development

Formal questionnaires soliciting related input were also developed. Two separate questionnaires document recent feedback gained from 50 Delta dispatchers and 20 Delta pilots regarding their prior experiences working with TAPS and E-Turb, respectively, as well as input from both groups on current turbulence tools, procedures, and related areas needing improvement. Personnel assigned to this work within Delta led the development of the questionnaires. Peer input on content was sought from all other in-service evaluation participants, and Dr. Amy Pritchett of the Georgia Institute of Technology was consulted for an academic review. Both questionnaires contained a majority of open-ended questions, and while this proved more difficult in analysis, it also yielded a richness and range of input that would not otherwise have been captured.

As reported in NASA's 5th WxAP Review on September 21, 2005,[5] current turbulence encounters are grossly under reported, and those PIREPS that actually are given are late, subjective, and not distributed to all users. In that same review, pilots' qualitative feedback validated the quantitative data obtained from the E-Turb radar, showing good correlation between turbulence warning and in-situ

[5] Robinson, Paul A. "Enhanced Turbulence Radar In-Service Evaluation," and "Turbulence Auto PIREP System In-Service Evaluation," September, 2005.

measurements of aircraft response. While also adding depth around these findings, the purpose of the questionnaires was to capture operational experience and feedback on uses of TAPS and E-Turb radar. In addition, through questions on current state activities, additional foundation for hypotheses regarding potentials in the realms of capacity enhancements and operational efficiencies were provided.

The general sections are described below, and follow a similar format for both groups so that comparisons could be made. Questions on respondents' backgrounds were also included to compare individual feedback against experience levels and types of experiences. Ultimately, however, these differences appeared insignificant given consistent answers on most questions.

1.7.1.1 General Turbulence Resources and Procedures (Section 1)

The main goal of this section was to determine the tools currently used by pilots and dispatchers, how often they are used, and the value of each one for the user. To further clarify current uses of turbulence information, we asked the two groups to define the most relevant data set for different phases of flight in a convective and clear air environment. A second goal in this section was to determine how often flights deviated from their original flight plan and the drivers for this decision.

1.7.1.2 Scenario-based Questions (Section 2)

This section was designed to present actual scenarios that occurred during the in service evaluation. Subjects were asked to respond based on their experience with the technologies during the evaluation period, which lasted from August of 2005 through January of 2006. The intent was to gauge whether the technologies were thought to be capable enough to change their normal behavior relative to turbulence.

1.7.1.3 Historical Uses of the Technologies (Section 3)

This section was designed to capture the subjects' reaction to the technologies based on previous uses in operations. They were asked to evaluate the technology based on how often they used it and how valuable it was in various situations.

1.7.2 Selection of Respondents

1.7.2.1 Dispatchers

Participation in the dispatcher questionnaire was solicited via a group email sent to all 135 Delta dispatchers, and the first 50 respondents expressing interest were included as subjects. This represented a statistically significant sample.

1.7.2.2 Pilots

Participation in the pilot questionnaire among Boeing 737-800 pilots was targeted towards those who had had experience using the E-Turb radar in convective weather, and participants were similarly included on a first-come, first-served basis. Although the pilot subject sample (20) was much smaller relative to the general 737-800 pilot population (800+), participation in the questionnaire was, again, limited to those pilots who had flight experience with the E-Turb radar.

1.7.3 Administration of Questionnaires

To encourage candor, all responses were anonymous. Questionnaires were administered via fifteen, two-hour sessions led by Delta project personnel, allowing participants to ask questions and request clarification as needed. No group was larger than five subjects. All questions in the questionnaire were read aloud by Delta project personnel, and respondents were asked to write in their answers only one question at a time before the group moved onto the next question.

1.7.4 Limitations of the Questionnaires

Though unavoidable, some limitations in the questionnaire data need to be considered. Feedback on uses of TAPS information by dispatchers is constrained by the fact that the questionnaires were administered several months after active work on the program concluded on January 31, 2006. Dispatchers continued to have access to the display of TAPS reports through approximately June of 2006. Based on answers given in the questionnaire, however, the time between the last day that the average dispatcher accessed TAPS and the day that the questionnaire was administered during November of 2006 was 9 months.

It should be noted, however, that the questionnaire was designed to compensate for this. Section 1 was meant to determine uses of current turbulence information (not including TAPS) and how often flights deviated from their original flight plan. Section 2 was meant to determine if the technologies were thought to be capable enough to change respondents' normal behavior relative to turbulence. The sample size was large enough to achieve exposure sufficient to inform answers in this section. Also, results consistently showed that based on an introduction to the technology during recurrent training sessions, as well as at least 5 months of exposure to the technology, subjects would indeed change their normal approach to turbulence if given TAPS information. Section 3 was used to evaluate TAPS from the standpoint of specific historical uses. Even though the average dispatcher recalled having the display of TAPS reports available only 12% of the time, responses indicated that this was mostly due to problems accessing and interacting with the display platform used for presentation of TAPS data, rather than the fact that the questionnaires were administered several months after the

conclusion of the program. General comments showed overall support for the technology, but complained about interfaces for the data.

As mentioned earlier, the pilot sample was relatively small, but the subject pool was based on exposure to E-Turb radar, which continued to occur through the writing of this report. Although equipage on only one aircraft yielded limited exposure to the technology, there was overwhelming support for the system, and the qualitative data supported the quantitative correlation provided by Rockwell Collins.

1.7.5 Analysis of the Questionnaires

Responses were collated in a spreadsheet and analyzed by sections as described in the section on “Questionnaire Development.” Comparisons were made between the pilots and dispatchers. From this, conclusions were made based on the percentage of responses for each question relative to the individual section. Overall conclusions were made and used in the recommendation section as well as Sections 2 and 3 of this report. The data were very consistent with the anecdotal evidence observed by members of the in-service evaluation and as documented in the 5th WxAP Review. There was also consistency in responses between the two respondent pools.

Analyses and summaries of these questionnaires are found in Sections 2 and 3 of this report. Also, the questionnaires themselves, including summaries of responses in tabular form as well as notes summarizing all input on a question by question basis, can be found in Appendices A and B. Raw data from the questionnaires were also provided separately to NASA in both electronic and hard copy formats.

2 In-Service Evaluation of TAPS - Dispatcher Questionnaire: Data Analysis and Results

2.1 *Procedures Used by Dispatchers to Identify Turbulence*

Section 1 of the questionnaire administered to dispatchers dealt with the tools and procedures currently utilized by dispatchers to identify areas of turbulence. From responses to Question 1, dispatchers appear to use a variety of tools in identifying areas of turbulence, including the turbulence forecast generated by the Delta Meteorology group, PIREPs and forecast products on the FAA's Aviation Digital Data Service (ADDS) website, PIREPs from company aircraft, and information from many other outlets. However, the data also showed that dispatchers generally feel forecasts of turbulence are reliable only 58% of the time on average. SIGMETs were viewed to be accurate only 15% of the time. Meanwhile, although most dispatchers acknowledged tremendous subjectivity in the information provided by PIREPs, they nevertheless represent the data source most prized by the group. Based on these responses, one recognizes that dispatchers are desperate for better tools both to locate and plan for turbulence.

2.2 *Procedures used by Dispatchers to Identify Aircraft for Avoiding Turbulence and Approach to Establish the Change*

Using many of the resources iterated in Question 1, dispatchers will generally plan around (vertically or horizontally) areas of moderate chop or turbulence when possible, placing much higher priority on PIREPs vs. information contained in forecasts.

Responses also revealed that once the flight plan is settled, instances in which dispatchers personally initiated a deviation (either horizontally or vertically) due to turbulence were relatively seldom. In fact, the average dispatcher estimate of how often areas of turbulence that were *not* forecast (but confirmed by PIREPs or other means) resulted in changes to preflight route planning was just 7%.

2.3 *Nature of Collaboration between Dispatchers and Pilots to Arrive at a Plan of Action*

During the preflight phase, particularly with respect to domestic flights, very little interaction between the dispatcher and flight crew occurs. Typically, flight plans are being sent by dispatchers to the FAA at about the same time as the crews who will execute those plans are arriving from previous flights. Flights are planned to avoid areas of turbulence, and the crew receives information on areas of possible turbulence via the weather briefing in the flight plan paperwork. Due to relatively high workloads on the flight deck as well as ATC constraints in terminal areas, climbout and descent are also phases when dispatcher input is minimal. Enroute,

however, depending on the dispatcher's workload, this interaction is much more significant, featuring mutual dialogue via ACARS.

It is important to note that in all phases of flight, turbulence caused by convection is viewed very differently from clear air phenomena. While convective SIGMETs and radar summary information are included as part of the weather briefing in the flight plan paperwork, crews tend to be primarily responsible for avoiding thunderstorm activity by use of the onboard weather radar from takeoff to touchdown. Since crews have no reliable detection systems for clear turbulence, dialogue between the dispatcher and pilots concerning these phenomena are much more prevalent.

2.4 *Dispatcher Estimates of Benefits Realized from TAPS*

Dispatchers were asked for their responses on their experiences with TAPS via the four metrics below, responding as follows.

a. Turbulence encounters avoided

Dispatcher Responses	
None	25
Possibly Once	3
Possibly Twice	4
Possibly Several	18

b. Airframe inspections avoided

Dispatcher Responses	
None	41
Possibly Once	5
Possibly Twice	3
Possibly Several	1

c. Reductions in traffic flow disruptions

Dispatcher Responses	
None	42
Possibly Once	2
Possibly Twice	1
Possibly Several	5

d. Other benefits (e.g. confidence in flight situation, workload etc.)

Dispatcher Responses	
None	21
Possibly Several	9
Useful check for PIREPS & Forecasts	21

Nearly all dispatchers had a great deal of confidence in the overall idea of TAPS information and how it could be used if integrated into the tools and interfaces with which they had greater familiarity.

2.5 *Scenario Based Questions*

By means of scenarios in which TAPS reports were available to inform dispatchers' operational decisions, Section 2 of the dispatcher questionnaire captured feedback on potential uses of TAPS information in 3 different settings, including convective and non-convective environments. All scenarios were based on actual occurrences where similar TAPS information was available on WebASD during the in-service evaluation.

Even though integration issues associated with the WebASD display and occasionally high workloads presented challenges in viewing TAPS data, nearly all dispatchers expressed confidence in the real-time, objective information provided by TAPS, and would have used that data to be more proactive in most cases. For example, with TAPS providing good information on turbulence of relatively low intensity and short duration through southern Colorado, 60% of dispatchers would have advised flights transiting this area to secure the cabin and remain at the most economical, flight planned altitude.

However, in the real world case on which this scenario was based, no dispatchers looked at the TAPS information, and without any knowledge about how long the turbulence might last, pilots made altitude deviations based on controllers' feedback. As a result, one flight burned so much more fuel than had been planned through this corridor that priority handling was considered for the arrival into the destination airport. In addition, dispatchers began planning flights transiting this area at lower, less economical altitudes.

2.6 *Historical uses of TAPS*

Section 4 of the dispatcher questionnaire was designed to provide estimates of benefits realized from TAPS based on uses of the system from August of 2005 until the feed of TAPS reports to the web based display platform was shut down in June of 2006. While detailed results per the NASA deliverables can be found in Appendix A, most dispatchers saw a great deal of intrinsic, philosophical value in TAPS data, and implied that limited integration constituted the primary barrier to actual uses of TAPS during the in-service evaluation.

Even though dispatchers were exposed to TAPS in formal training sessions, no airline procedures were ever developed or in place for handling the data. Although TAPS was used in a few instances to provide additional guidance to Delta captains in deciding whether or not to order airframe inspections following encounters with significant turbulence, TAPS data did not govern in these considerations. Three of the 50 dispatchers that were surveyed regarding TAPS stated that they had used the product in deliberations regarding severe loads. Half of the dispatchers could not recall specific times when TAPS could have been helpful in avoiding a turbulence encounter, and 82% could not recall a time when TAPS could have helped in avoiding an airframe inspection. 84% of respondents could not recall a situation in which TAPS could have proved helpful in reducing traffic flow disruptions, and 88% stated that they had never been asked about TAPS by a Delta pilot.

As documented in Appendix C and in the feedback contained in the questionnaires, dispatchers and meteorologists were also dissatisfied with the scarce number of TAPS reports that were usually visible on the WebASD display. Because TAPS relies on the ACARS VHF datalink to downlink TAPS messages to groundstations, the project team was conservative in setting the rms “g” threshold for TAPS reports to be generated. This was intended to minimize datalink expenses as well as prevent excessive clutter on WebASD. WebASD also allows users to select the severity of encounters to be displayed on the screen. For example, dispatchers can choose to display only moderate encounters and above. Although project personnel emphasized this feature during recurrent training and individual interviews at dispatcher workstations during the summer and fall of 2005, it is possible that many dispatchers either did not understand this function or forgot how to use it. Still, the default display threshold for a new user opening TAPS on WebASD was .10 rms “g,” which is very close to the minimum threshold for a TAPS report to be generated. Additionally, equipage on just 123 aircraft was perceived by some as not nearly sufficient to deliver the degree of geographical coverage required to deliver significant operational value.

It is important to note that most dispatchers lacked the integrated toolset necessary to make the data truly relevant to the operation on even a fairly basic level. In explaining one reason why TAPS proved of limited use at Delta, many dispatchers cited the display platform used for presenting TAPS information as a significant barrier to their assimilation of the data. 54% felt that the WebASD platform was inadequate, and most of the remaining respondents also commented that they would have preferred to have the data presented on a more integrated and familiar display. With screen space for displaying a wide variety of more primary flight planning applications already limited, WebASD was yet another website for dispatchers to pull up, configure and monitor. Had TAPS data been integrated into Delta’s in-house flight following display, operational uses surely would have been more numerous. Data from questionnaires confirm this as a

major factor limiting the system's usefulness; however, tool integration was beyond the scope of the TAPS developmental activities.

Most significantly, all dispatchers perceived a high level of inherent value in the data and were open to using it provided such issues could be overcome. 76% of dispatchers felt TAPS was timelier than conventional PIREPs, and 90% felt that it also provided information on turbulence that was both more objective and geographically accurate. Although 62% had never referenced TAPS in making flight-planning decisions, 88% felt that the product could be very useful in doing so. More than anything, feedback such as this points to the need for continued work to yield an integrated solution that could also be utilized by pilots, ATC, and other stakeholders.

2.7 *Dispatcher Questionnaire Summary and Conclusions*

Overall, feedback in the questionnaires administered to dispatchers confirmed that current tools, available prior to TAPS, and techniques for locating, avoiding, and preparing for turbulence are inadequate. While a variety of resources are utilized, dispatchers' faith in the information provided by those resources is minimal. As a result, the group estimated that flight crews are frequently operating on a tactical basis, relying in many cases independently on turbulence that they either encounter or hear about over ATC frequencies to drive their decisions. In quantifying the extent of this approach, dispatchers estimated that crews deviate from the most economical, flight planned altitude due to turbulence approximately 32% of the time, remaining at those altitudes for an average of 41 minutes. Such estimates implicate the lack of objective, high quality turbulence data in significant safety, economic, and environmental impacts.

Even though uses of TAPS as part of the in-service evaluation were limited, data from dispatchers affirmed the group's belief in the objective information provided by TAPS and its potential in satisfying important informational needs. Responses also suggested that maximum equipage, including automatic turbulence reporting by other airlines, would be required in order to provide the level of data necessary to deliver significant safety and operational benefits. However, dispatchers were perhaps most emphatic about the need for turbulence encounter data to be integrated into their operational platforms, also indicating the importance of pilots and air traffic controllers sharing the same information. With the help of wider equipage, more formalized procedures, and integration of TAPS into a flight following display more familiar to dispatchers, these issues could be overcome.

3 In-Service Evaluation of E-Turb Radar - Pilot Questionnaire: Data Analysis and Results

3.1 *Procedures Used by Pilots to Identify Turbulence*

Several questions in Section 1 of the Pilot Questionnaire looked at tools and procedures used by pilots to identify areas of turbulence. In general, data show pilots generally look at fewer sources for turbulence than dispatchers, potentially because their training and overall access for many sources is relatively limited. Responses also show that the most used and trusted source for pilots are comments regarding ride quality transmitted over the ATC frequency. Flight Plan Weather, a compilation of Forecasts and PIREPS, along with Dispatcher Input are the next most used sources, with reasonable confidence levels.

The most used and generally trusted source of information for dispatchers, the Delta Turbulence Forecast, is seldom used or trusted by pilots. Although Delta Meteorologists are contacted infrequently to inform turbulence related decisions, the pilots seem to have a reasonable level of confidence in their input. Also, as part of questionnaire responses, many pilots included comments regarding the subjectivity and erratic nature of PIREPS (e.g. different turbulence levels reported in same area by different crews). In summary, pilots, like dispatchers, have to rely on forecasts that they feel are only correct a little over 50% of the time, and PIREPs that they paradoxically appreciate a great deal but also find unreliable.

Again, a major distinction is made between approaches to clear air turbulence vs. convective turbulence. For thunderstorm activity, pilots generally reference a Nexrad radar picture when available during preflight, while also taking note of any frontal activity or Convective SIGMETs in the flight plan paperwork. Once airborne, the onboard weather radar is the tool most utilized, and most crews reference the path taken by aircraft ahead for additional guidance. Also, while 50% of the group stated that they use the current generation Weather + Turbulence function on a routine basis in convective environments, 60% found the information it provided to be either “Occasionally valuable, but usually unreliable or misleading” or only “Somewhat Valuable most of the time.” Instead, comments indicated that pilots tended to use information on radar reflectivity to guide their decisions, correlating areas of high reflectivity with turbulence hazards.

For clear air phenomena, although interaction between the pilots and dispatchers via ACARS is more prevalent, the responses also show unambiguously that pilots use reports of turbulence made over ATC frequencies as their primary source of information in all phases of flight.

3.2 *Procedures Used by Pilots to Request Avoiding an Area of Turbulence and Approach to Establish the Change*

For convective phenomena, pilots generally will rely almost exclusively on the onboard weather radar in guiding decisions, making a request to deviate laterally with the controller working the ATC sector. These requests are nearly always accommodated enroute, but higher traffic density leads to greater uncertainty when operating in the terminal area. Most pilots are also careful to note the wind information available on the navigation display when requesting deviations, avoiding the portion of storms that are downwind whenever possible.

To avoid clear air turbulence enroute, pilots generally will seek the altitude that is rumored to be smoothest over the ATC frequency by making a request with the controller. As noted in responses to Question 9, pilots either receive or request re-routes due to turbulence in only 6% of cases.

Of additional interest were the turbulence thresholds that pilots use in deciding to deviate from the flight plan. For passenger comfort, 75% of the responses indicated that pilots look to initiate a change when experiencing either “light chop” or “light turbulence.” Feedback from the questionnaires administered to dispatchers, meanwhile, indicated that most dispatchers plan around areas of moderate chop or turbulence.

3.3 *Nature of Collaboration Between Dispatchers and Pilots to Arrive at a Plan of Action*

During the preflight phase, pilots generally have very little if any involvement in flight planning, relying instead on the knowledge and good judgment of the dispatcher, as well as the additional tools at his disposal. Also, once enroute, 75% of the pilots surveyed feel that the role of the dispatcher tends to be more reactive than proactive with respect to turbulence.

For convective phenomena in all phases of flight, responses to Question 5 show that the role of the dispatcher is perceived by the pilots to be minimal, with very little mutual dialogue regarding the nature of the plan.

With respect to clear air turbulence, although dialogue via ACARS between pilots and dispatchers is more prevalent, responses to Questions 6 and 8 show that ride reports over the ATC frequency are seen as the primary drivers in executing what appears to be a very reactive plan in response to turbulence. Answers to question 8 show that a request is made with the controller based on reports made over the ATC frequency in 95% of cases, while dispatchers are consulted – time permitting – concerning options 45% of the time. Collaboration and dialogue between pilots and dispatchers occur least during climbout and descent.

3.4 *Pilot Estimates of Benefits Realized from the E-Turb System*

Although many pilots wished that E-Turb could be presented at ranges greater than 25 nautical miles, nearly all respondents voiced much higher confidence in the turbulence information presented by the E-Turb radar capability versus legacy systems. Respondents also mentioned times when the E-Turb gave invaluable information on potentially hazardous turbulence in areas of low radar reflectivity. Even though the technique of inferring that areas of high radar reflectivity implied areas of hazardous turbulence was well-established, of pilots who were asked to choose between a routing into (1) an area with little reflectivity where E-Turb predicted turbulence was present and (2) an area of relatively high reflectivity but *no* E-Turb predicted turbulence, all opted to transit the latter. Armed with better information on the actual turbulence hazard versus raw reflectivity, this level of confidence in the information provided by E-Turb represents a paradigm shift in the way returns on airborne weather radar are viewed in the future.

Similarly, as an alternative to raw reflectivity, dispatchers also responded favorably to the idea of downlinked E-Turb information being presented at their workstations. Beyond this, however, the dispatchers had no context for providing answers on how the system provided benefit during the in-service evaluation.

Pilots were asked for feedback on their operational experiences with E-Turb via the four metrics below, responding as follows.

a. Turbulence encounters avoided

Pilot Responses	
None	4
Possibly Once	2
Possibly Twice	0
Possibly Several	14

b. Airframe inspections avoided

Pilot Responses	
None	14
Possibly Once	3
Possibly Twice	2
Possibly Several	1

c. Reductions in traffic flow disruptions

Pilot Responses	
None	8
Possibly Once	2
Possibly Twice	3
Possibly Several	7

d. Other benefits (e.g. confidence in flight situation, workload etc.)

Pilot Responses	
Confidence in Forecast	3
Confidence in PIREPS	4
Confidence in new E-Turb Magenta	10
Situational Awareness	10
Reductions in ATC congestion	1

Negative experiences with the E-Turb radar seemed to be primarily the result of limited exposure to the technology. With the remaining 70 Boeing 737-800s in the fleet equipped with legacy weather radar units, there were some instances of pilots misunderstanding the Multiscan/E-Turb unit's capabilities. Also, a few pilots stated disappointment with the information provided in automatic mode, when in fact they had based these comments on inadvertent operation in manual mode. In all such instances, poor performance as a result of problems related to the unit's automatic mode or E-Turb could not be substantiated.

Beyond issuance of Flight Crew Bulletins, articles in Pilot Information Packets, the information provided by Delta jumpseat occupants from time to time, and the onboard supplement, it was also not feasible for Delta to invest the training necessary to overcome some of these issues given limited E-Turb equipage. When asked about how the system might have proven helpful in more expedited routings, for example, many pilots lacked a complete picture of how the E-Turb technology could be used in such considerations. Most pilots saw the intrinsic value in the E-Turb radar, but their responses to many questions underscores how equipage on just one airframe and no sharing of E-Turb information with airspace decision makers limited the potential usefulness of the technology. The need for work to continue in order to ascertain how E-Turb might be used to supplement a comprehensive, integrated solution to convective turbulence and accompanying airspace challenges is therefore paramount.

3.5 *Scenario-Based Questions*

By means of scenarios in which information on TAPS reports and E-Turb was presented to inform pilots' operational decisions, Section 2 of the pilot questionnaire captured feedback on potential uses of this information in 3 different

settings, including convective and non-convective environments. All scenarios were based on actual occurrences during the in-service evaluation.

When given information by the dispatcher concerning an area where in-situ data such as TAPS confirmed turbulence of known intensity and relatively short duration, pilots showed uncommon comfort with the option of accepting degraded ride quality while remaining at the most economical, flight planned altitude. This approach stands in direct contrast to the one usually taken in the absence of such information, as crews climb and descend in search of smooth altitudes. Results such as this underscore how better information can allow crews to prepare for turbulence, leading in turn to better operational outcomes.

Another scenario asked pilots which path they would take if the E-Turb radar showed an area of yellow (moderate) reflectivity but no magenta, and another area of green reflectivity but solid magenta. Trusting the hazard information provided by the E-Turb, 100% of pilots stated that they would transit the area of yellow reflectivity, abandoning the long-standing practice of basing such decisions solely on reflectivity.

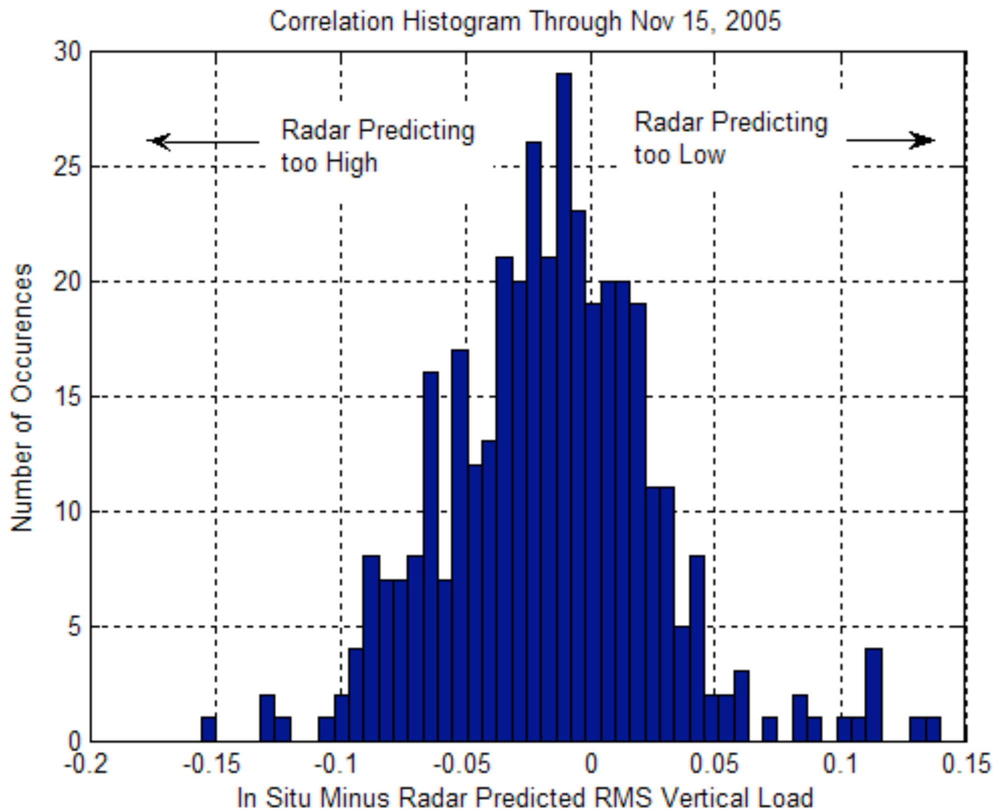
3.6 *In Service Correlation Data (Courtesy of Rockwell Collins)*

The qualitative experience of the pilots who worked with the E-Turb radar was very positive as discussed previously. To correlate those experiences against quantitative data regarding E-Turb performance, the following brief description and histogram document quantitative methodology and results.

As mentioned in the E-Turb Technology Description, the WXR-2100 with E-Turb radar flown aboard one Delta aircraft during the in-service evaluation was equipped with a built-in data recording system. The recording system stored radar scan data and included turbulence and reflectivity along with in situ vertical accelerometer information, airspeed, altitude, aircraft position, and other relevant aircraft parameters. The recording system was automatically activated when in situ acceleration exceeded a specific threshold or when radar predicted turbulence levels exceeded a specific threshold. Once activated, the recorder stored turbulence and reflectivity sweep data until the event passed behind the aircraft. Approximately once per month, the radar recording system was accessed and data were downloaded and post-processed.

From August 25, 2004 to November 15, 2005, a total of 798 turbulence encounters were recorded. Of these encounters, 378 events indicated that the crew actually penetrated some level of predicted turbulence such that correlation between the predicted turbulence of the E-Turb radar and in situ turbulence could be made. The resulting histogram shown below summarizes the correlation. Based on the mean of the correlation error, the radar slightly over predicts turbulence events. Some of this 0.016 g over prediction can be explained by the offset between the

aircraft CG and accelerometer. The distribution of correlation error has a Gaussian appearance with a standard deviation of 0.043 g.



3.7 *Pilot Questionnaire Summary and Conclusions*

Pilots rely heavily on PIREP data in which they often have ironically little confidence. Also, once enroute, their overall approach to turbulence appears to be very reactive. With very little real-time knowledge on the state of the atmosphere, pilots appear to find the smoothest flight level through trial and error, based primarily on the weather radar and reports of turbulence over the ATC frequency. They voiced strong support for the type of data that could be provided by an automatic turbulence encounter reporting system such as TAPS.

For convective phenomena, pilots currently rely primarily on the airborne weather radar, correlating high levels of radar reflectivity with turbulence hazards. Their experience working with the E-Turb radar, however, was very positive. Even though crews have little confidence in current generation magenta systems, responses to Question 14 showed perhaps most dramatically how crews trust the information provided by the E-Turb radar, deviating even around areas where magenta overlaid areas of very little or no reflectivity.

4 In-Service Evaluation Conclusions

When Delta's involvement in TPAWS began, it did so under the charter of new tools and technologies aimed at enhancing aviation safety for the traveling public. As enablers of better and timelier information for various users to leverage in avoiding turbulence hazards, TPAWS and related technologies remain firmly rooted in the safety arena. But considering the broader weather related challenges facing an airline, air traffic managers, and the traveling public, other transferable benefits in the areas of airspace utilization and economic efficiencies were quickly realized. To understand exactly how and where these synergies apply, one must first understand responses to turbulence within the current National Airspace System. It should be noted that although in narrative format, the description of the system that follows is validated by the feedback in the pilot and dispatcher questionnaires that were gathered as part of this in-service evaluation.

For the average Delta pilot flying primarily domestic routes, limited opportunity exists to view weather information beyond what appears on the weather briefing/flight plan paperwork. With pilots often facing very little time between flights, dispatchers may advise of the potential for areas of turbulence and convection in the remarks section of the flight plan, and company PIREPs along the route of flight are always included as part of the briefing. Unfortunately, company PIREPs are incorporated as secondary information within position reports, and refer only to the turbulence encountered since the previous reporting point, seldom resulting in a comprehensive or accurate picture. Even though progress in this area has recently been made as a result of new capabilities on the FAA's Aviation Digital Data Service (ADDS) website, those reports that do make it into the FAA's database of official PIREPs remain generally scarce, and depending on the workload and conscientiousness of the dispatcher, these may or may not be included in the flight plan paperwork.

Moreover, since PIREPs of turbulence are always dated and based on the subjective interpretation of any given pilot flying any different size of aircraft, their dissemination often proves counter-productive, particularly for a phenomenon as dynamic as turbulence. As an example, the pilot of a regional jet reports moderate turbulence at Flight Level 310 while climbing out of a busy terminal area towards cruise altitude. Armed with very little information concerning the *real* intensity of the turbulence and its expected duration, controllers working flights and dispatchers planning flights then take a cautious approach, making that airspace inaccessible to *all* aircraft, including larger airframes which that turbulence may not threaten.

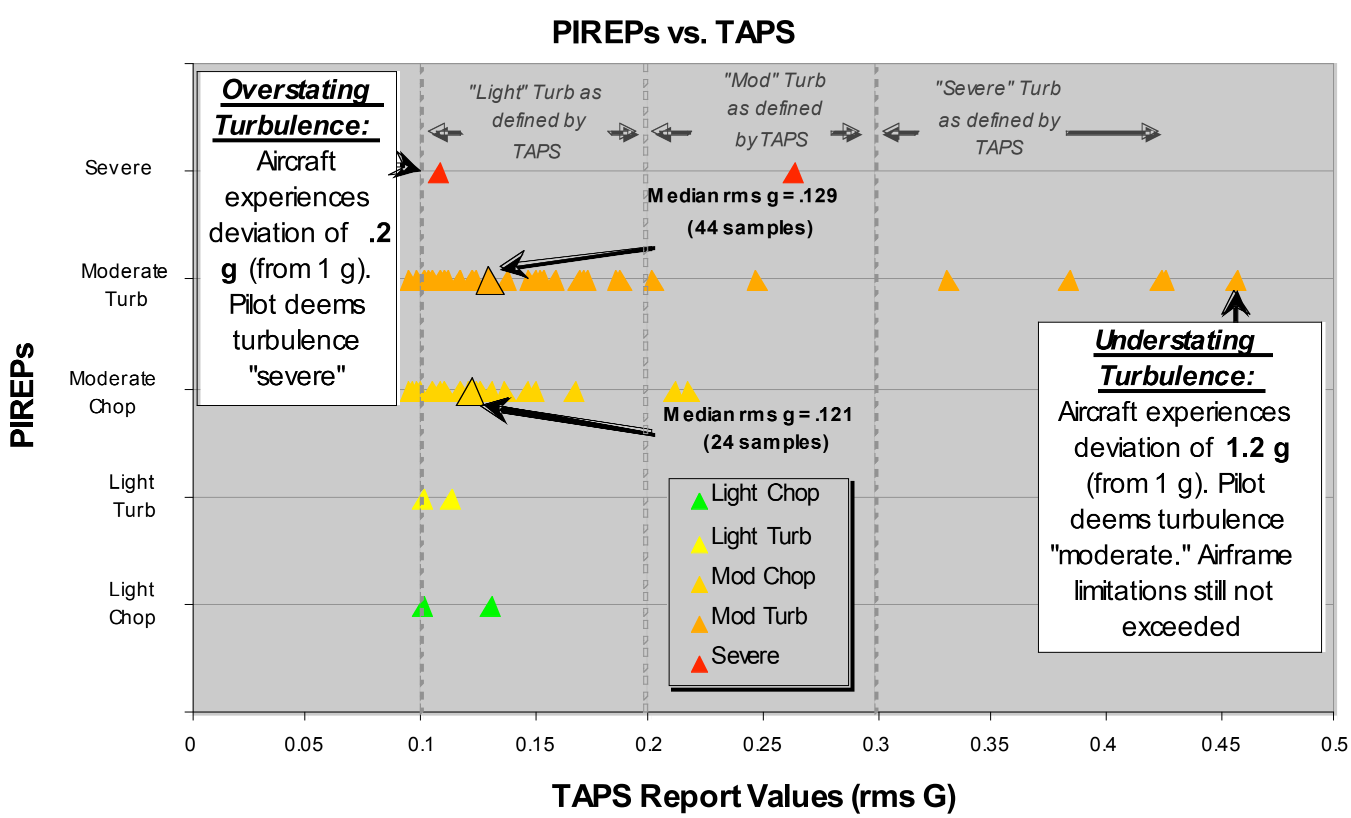
Through access to ACARS flight histories, jumpseat observations and conversations with pilots and dispatchers, Delta project personnel compiled a dataset comparing TAPS data against conventional PIREPs, as depicted below in Figure 1. Consisting of data gathered by project personnel viewing TAPS on WebASD between June of 2004 and October of 2005, 74 PIREPs, summing up

turbulence that coincided with 316 TAPS reports on equipped aircraft, were plotted against average rms g values contained in corresponding TAPS reports. Only PIREPs made within 5 minutes of one or more TAPS reports, or PIREPS that in some other way specifically referenced the turbulence that coincided with one or more TAPS reports, were considered for comparison in the chart below.

As an example of how one datapoint could be generated, 3 TAPS reports of .100 rms g, .110 rms g and .120 rms g are made on Delta flight 123. Within 5 minutes of those TAPS reports being generated, a PIREP of "Moderate Chop" is made via ACARS by a crewmember of flight 123. The resulting datapoint plots an average rms g value of .110 on the x-axis against "Moderate Chop" on the y-axis. Also significant are 19 PIREPs, ranging from Light to Severe Turbulence, which did not coincide with any TAPS reports. In these cases, it is assumed that the upset caused by the turbulence did not meet the threshold for a TAPS report to be generated.

The results confirm the broad spectrum of subjectivity in conventional PIREPs, further underscoring the need for better information to drive better operational decisions.

Figure 1



*Due to a lack of corresponding TAPS reports, not included are 3 PIREPs of light turb, 11 of mod chop, 4 of mod turb, and 1 severe. In these cases, turbulence was assumed to be below the TAPS reporting threshold of approximately .1 rms "g".

Compounding the issue even further is an apparent disparity between what most pilots perceive as turbulence significant enough to merit an altitude change, versus the level of turbulence that dispatchers plan flights to avoid. In the questionnaires distributed to pilots and dispatchers at Delta, participants were asked about their tolerances in planning for and reacting to various levels of turbulence. The results revealed that pilots often tend to seek smoother air at the first signs of "light chop" or "light turbulence," while dispatchers tend to plan around areas of moderate chop or turbulence. This leads to further discrepancies in perceptions relating to the accuracy of forecasts, and pilots' perceptions as to the conscientiousness of dispatchers.

As a result, in non-convective environments, pilots resort to discussion about ride quality over Air Traffic Control (ATC) frequencies as their primary tool in driving tactical decisions regarding deviations and altitude changes. But because the information circulated by controllers concerning turbulence is (1) always subjective, (2) often dated, and (3) confined only to the airspace over which they have responsibility, pilots often have a very inaccurate picture of the intensity or duration of reported turbulence. Yet, for non-convective turbulence affecting primarily the cruise phase of flight, this in fact is what currently drives utilization of the National Airspace System (NAS) on a day-to-day basis. In fact, 100% of pilots who participated in the questionnaire considered reports of turbulence on ATC frequencies as a primary tool in turbulence detection and avoidance. The result is a highly inefficient use of airspace, as pilots scramble to find the smoothest air possible by trial and error from one ATC frequency to the next. It should be noted that this is in no way intended as an indictment against the best practices of any user mentioned here. Rather, it is simply the best possible outcome of a system that lacks truly objective, real time information concerning the state of the atmosphere and its impact.

The consequences of this methodology are multifaceted and expensive, affecting pilots, dispatchers, controllers, airlines, and the traveling public. Consider, for example, the following scenario. An aircraft experiences one to two minutes of light chop, prompting the pilot to seek an alternate altitude. After being notified about the chop, the controller then relays this information to others inquiring about rides. As other pilots checking onto the frequency and dispatchers planning flights at Airline Operations Centers hear about the report, an entire flight level is essentially eliminated from the system on a *de facto* basis. In the end, results include congestion at other flight levels, ATC delay programs due to pressure on enroute spacing, and higher fuel burns due to largely unnecessary avoidance of the most economical altitudes.

Consider now that the turbulence that triggered all this was isolated, lasting just five minutes with no change in intensity. Perhaps the pilot who made the report had a low tolerance for turbulence on that particular day. Had aircraft in this sector

been equipped with an automatic in-situ turbulence reporting mechanism, the duration and true intensity of the turbulence may have been more evident, giving crews and dispatchers confidence in transiting the area and enhancing airspace utilization. In fact, in the questionnaires conducted at Delta, pilots were unambiguous in their willingness to ride out such patches of turbulence if presented with better information in the form of automatic reports such as TAPS. Preliminary analysis conducted by the Delta Air Lines Flight Operations Engineering Group puts the cost to domestic flag carriers of added fuel due to deviations from the most economical altitudes at anywhere from $26 million to more than $210 million annually. The cost of airspace lost to such inefficiencies remains unknown, but could be significant.

Meanwhile, the abundance of small-scale data that would have been gained from atmospheric in-situ reports in the above scenario could also have fed forecast models for better planning by dispatchers and better strategic traffic management at the ATC Command Center. Given all that is at stake for the well being of the NAS and the potential to advance the NGATS vision, narratives such as these highlight an important opportunity to conduct basic human factors research on how this information should be presented to relevant stakeholders.

In convective environments, similar potentials exist for uses of E-Turb information. Currently, pilots, using airborne weather radar units, as well as controllers and dispatchers, using ground based Nexrad radar, correlate high levels of radar reflectivity with areas of hazard, including hail and severe turbulence. While this correlation may be on target in many cases, reflectivity on any weather radar display is, in its essence, merely a measurement of precipitation density. Depending on the nature of the system, areas of turbulence that are actually hazardous to transport aircraft may be relatively localized within much larger areas of high reflectivity. Meanwhile, significant turbulence hazards may exist nearby but in areas of low reflectivity, as has been documented in numerous incidents and accidents in the past. But because the only tool available for avoiding such hazards is a depiction of reflectivity, pilots, controllers, and dispatchers tend to be very conservative when operating in the vicinity of convection, sacrificing what are suspected to be very large areas of usable airspace.

With E-Turb airborne weather radar units pinpointing the locations of actual turbulence hazards, together with real-time actual turbulence encounter reports to validate the locations and intensity of turbulence in these areas, pilots, dispatchers, and controllers could make much better decisions regarding operations near convection, confidently exploiting much of the airspace in these areas that goes wasted today. Such information would reduce ground delay programs due to thunderstorms, and also result in potentially significant fuel savings due to more expedited routings. In questionnaires conducted at Delta, pilots who had flown the Boeing 737-800 equipped with E-Turb radar were asked which direction they would fly if the E-Turb predicted a large area of turbulence (solid magenta) in an area of low reflectivity (green) and another area with no

predicted turbulence in an area of moderate reflectivity (yellow). Trusting the E-Turb information, 100% of pilots voiced comfort transiting the area of higher reflectivity (yellow). On the ground, a majority of dispatchers also responded that downlinked E-Turb radar information would be helpful in relaying strategic guidance to crews that would be operating in the vicinity of convection.

Considering the safety challenges posed by pending airspace constraints, together with the JPDO's activity in driving towards the NGATS, the integration of automatic turbulence encounter reports and E-Turb radar information could make significant contributions to safety, better airspace utilization, and more efficient operations. Key ingredients in satisfying such a vision include (1) wide equipage by multiple carriers, (2) the right datalinks, interfaces, displays and decision support tools for handling the data, (3) pilots, dispatchers, meteorologists and controllers all using that data to aid in tactical and strategic decisions, and (4) perhaps most importantly, educated users and decision makers.

5 Turbulence Needs and Delta's Recommendations for Future Research

5.1 Overview

As detailed above, Delta's participation in the in-service evaluations of TAPS and E-Turb technologies as part of the NASA Weather Accident Prevention (WxAP) Project yielded very positive results. As a subset of weather issues affecting the National Airspace System (NAS), turbulence represents a major constraint to airspace utilization, resulting in excessive fuel burn with current avoidance strategies creating significant penalties in economics and emissions. Based on the transferable benefits that were realized in this laboratory environment and Delta's perspective as an end user, what follows in this section are Delta's recommendations for follow-on research efforts as related to the requirements of the Next Generation Air Transportation System (NGATS).

5.2 Current State & Drivers for Turbulence Research

5.2.1 Current State

Overall, feedback in the questionnaires administered to dispatchers confirmed that current tools and techniques for locating, avoiding, and preparing for turbulence are inadequate. While a variety of resources are used, dispatchers' faith in the information provided by those resources is minimal. As a result, the subject group estimated that flight crews are frequently operating on a tactical basis, relying in many cases independently on turbulence that they either encounter or hear about over ATC frequencies to drive their decisions. When asked to quantify the extent of this approach in questionnaires, dispatchers estimated that crews deviate from the most economical, flight planned altitude due to turbulence approximately 32% of the time, remaining at those altitudes for an average of 41 minutes. Pilots, meanwhile, felt that these occurrences were more than twice as numerous in their responses. Such estimates implicate the lack of objective, high quality turbulence data in significant safety, economic, and environmental impacts.

Similar to feedback obtained from dispatchers, pilots rely heavily on PIREP data in which they tend to have very little confidence. Once enroute, their overall approach to turbulence generally appears to be very reactive. With very little real-time knowledge on the state of the atmosphere for clear air phenomena, pilots appear to find the smoothest flight level through trial and error based primarily on reports of turbulence over the ATC frequency. For convective phenomena, pilots currently rely primarily on the airborne weather radar, correlating high levels of radar reflectivity with turbulence hazards.

5.2.2 Technical & Economic Issues

5.2.2.1 Technical Drivers

Incorporation of technologies that address the forecasting, now-casting, and reporting of turbulence will be vital in devising a comprehensive solution to the turbulence problem. For tactical knowledge regarding turbulence, a combination of data such as E-Turb radar returns and actual turbulence encounter reports will be needed to satisfy "now casts" of turbulence that users might expect within three to thirty minutes. Strategically, while reliable forecasts of turbulence represent the best solution, reporting will still be needed, since improvements in this area will depend largely on a critical mass of relatively small scale, automated observations and in-situ turbulence reports.

Another important element in this solution involves the evolution of another turbulence reporting technology. Refinement and deployment of a turbulence reporting metric called Eddy Dissipation Rate (EDR) was proceeding at another major US carrier. Developed by the National Center for Atmospheric Research (NCAR), this non-proprietary metric was viewed as a complement or potential alternative to TAPS within industry circles. While TAPS categorizes an encounter with turbulence based on the resulting aircraft "g" response, EDR describes the normalized atmospheric disturbance responsible for the upset. Since EDR measures the atmosphere, many meteorologists from a conceptual standpoint value it more highly than the type of data provided by TAPS. EDR is also seen as an essential component in promoting better turbulence forecasts, and is planned to have input into the next iteration of the Graphical Turbulence Guidance (GTG) forecast product available via the FAA's Aviation Digital Data Service. By the fall of 2005, two major US carriers had also committed to reporting EDR, though it had yet to be deployed at one carrier.

Debate concerning the merits of both technologies, however, is lengthy and complex, and confusion within the industry on how best to move forward lingers. EDR was named as the standard for turbulence reporting by the International Civil Aviation Organization (ICAO); however, in early 2006 the FAA recommended that carriers adopt TAPS in Advisory Circular 120-88A.

Delta is in the process of finalizing a contract to install EDR on its aircraft, representing an important opportunity to explore the roles, capabilities, and overall value of each metric. To the extent that resources can be aligned towards an experimental program incorporating a side-by-side comparison, one is strongly encouraged.

Whichever technology or combination of technologies is implemented, integration of the data will be a key driver in the relevance and, therefore, the technical success of what is implemented. In responses to the questionnaire and other feedback gained from dispatchers during the in-service evaluation, dispatchers

were perhaps most emphatic about the need for in-situ data to be integrated into their operational platforms as a means of improving utilization. Given the nature of the interaction between pilots and dispatchers that was also detailed in the questionnaires, ensuring that both parties have access to the same turbulence data will be important. Controllers, as airspace decision makers, will also need to share in turbulence reports and E-Turb data in order to derive many of the operational benefits iterated in this document. Additionally, even though users will need to share in the same data, how that data is presented will likely need to be different given the different missions of individual users. It is clear that without appropriate attention to such issues, even data that users respect will go ignored by the majority of the user population.

5.2.2.2 Economic Drivers

Aside from the albeit important technical discussion surrounding these technologies, three issues are primary for the industry. Firstly, as with any technology, the solution must be cost effective for the airlines. Secondly, as shown in the feedback collected from pilots and dispatchers in Sections 2 and 3, the toolset currently being used is so deficient in meeting airline and NGATS needs that adoption and integration of either technology would represent a major leap forward. Thirdly, with adequate coverage representing perhaps the primary ingredient in the success of either metric, achieving critical mass in aircraft equipage will most likely decide the path that airlines pursue, easily overtaking any lingering technical differences. Put another way, because the industry is marginally profitable and starving for better tools, the better technology may not be the one that ultimately gets adopted. Although Delta and most others in the industry remain open to the possibility that EDR and TAPS represent complementary technologies, as iterated above, a side-by-side comparison to determine the extent to which they satisfy various users' requirements, areas where they overlap, as well as areas where differences satisfy the unique needs of users appears needed.

The need for solutions that are cost effective presents additional research challenges in two main areas. Expenses related to the datalinking of turbulence data must be minimized, and the training necessary for end users to leverage the data effectively must be streamlined as much as possible.

Underscoring the importance of datalink costs, it is Delta's understanding that although EDR is deployed at one major US carrier, not all of the carrier's equipped aircraft are currently making reports due to excessive datalink expenses. Meanwhile, entire airplanes have been designed around issues related to training expenses at airlines. Often, these design programs sacrificed significant advances in technical capability in order to satisfy the training budgets of the end user. Perhaps the most striking example of a manufacturer's sensitivity to these issues occurred on various iterations of the Boeing 737. Even when Boeing

decided to revolutionize the cockpit on 737 New Generation models by instituting flat panel displays on the main instrument panel, it left a relatively antiquated design for the overhead panel alone. Using the flat panel displays, it also gave operators the option of displaying the same gauges in the same format as crews of previous editions of the aircraft had been accustomed. The point of all this is that items seemingly so insignificant as expenses related to datalinks and training drive crucial design points for the airlines, and the same needs to be true of systems and interfaces aimed at solving the turbulence problem and related airspace constraints.

5.2.2.3 Economic Costs of Poor Turbulence Information

The importance of one particular discovery became increasingly evident over the course of the in-service evaluation. Based on jumpseat observations by project personnel and prior experience as a Delta pilot, the importance of giving passengers as smooth a flight as possible stood out as a clear element in the culture of Delta flight deck crewmembers. As a result of this observation, and in dialogue with the lack of quality information on turbulence under the current system, members of the project team hypothesized that the economic cost of deviations from the most economical altitudes due to turbulence was potentially very large. To validate this scientifically, pilots and dispatchers were asked in the questionnaires for estimates on (1) what percentage of time flights deviated from the optimum altitude and (2) how long those flights remained off altitude once the change had been made. The dispatchers estimated that these deviations occurred on approximately one third of flights, and the pilots estimated that they occurred on two thirds of flights. Estimates of how long the flights were off of the optimum altitude varied by the type of flight. Narrow body flights with shorter enroute time were estimated to be 39 minutes, and the wide body segments with longer times to be 53 minutes. Admittedly, these are small samples, but anecdotal evidence based on experience as a Delta pilot and observations on the jumpseat seem to confirm the data.

Using data from the questionnaires as referenced above, the analysis in Table 1 took a typical airline, and computed the additional fuel penalty of deviating from the most economical altitude by four thousand and two thousand foot intervals. These intervals were chosen since, for the pilot’s direction of flight, the crew must climb or descend by at least these intervals while seeking smooth air. The fuel burn for that airline was calculated based on six different aircraft types. At that point, segment data for the 11 major airlines was incorporated. The base airline with 6 aircraft types was used as the model for the other airlines, and a ratio was used to get the total gallons of additional fuel for the 11 major airlines if 100% of segments were off altitude for the times described earlier. At that point, estimates of 66% and 33% of flights were used to provide sensitivity analysis.

The analysis showed that a significant amount of fuel may potentially be wasted due to anachronistic turbulence avoidance practices, affecting both airline economics and the environment. The key to avoiding this cost is rooted in better turbulence data and procedures to deal with it objectively. As documented in answers to Scenario-based questions in the questionnaires, both pilots and dispatchers maintain that they would be more apt to remain at the most economical altitudes if armed with better information.

Table 1

11 Major Airlines					
	Total Gal	**Fuel Cost**	**$ if All Flights Off Alt**	**Est. of Flights In Percent**	**Total System $**
Fuel/Year if Off 4000 feet	159,460,057	$2.00	$318,920,115	66	$210,487,276
Fuel/Year if Off 2000 feet	40,508,729	$2.00	$81,017,457	66	$53,471,522
				33	$105,243,638
				33	$26,735,761

5.3 Specific Delta Recommendations

5.3.1 Next Generation Air Transportation System (NGATS) Requirements

5.3.2 General Areas

Given lack of good turbulence information and the way in which weather is viewed under the current system, there is an immense need for work aimed at the fundamental human factors and training implications of the paradigm shift required in order for enhanced turbulence information to actually be leveraged by users. The role of end users in defining these design points will be crucial. While these represent vast research challenges, the findings of this evaluation represent a foundation for responding to NGATS needs.

As additional background, one especially important aspect of the work being conducted by the JPDO deals with how sensors – both on the aircraft and elsewhere – can be used as nodes in enabling the NGATS.[6] To enhance airspace capacity and maintain or enhance current safety levels within the National Airspace System (NAS), autonomous sensors will be relied upon extensively in supplying a constantly updated, vast array of data, including weather information, to drive decisions on routing and airspace usage. This constant feed of data is envisioned to provide the precision necessary to make these decisions more intelligently than under the current system, exploiting airspace opportunities that go wasted today. With sensors providing more precise, higher fidelity information

[6] Joint Planning and Development Office. "Next Generation Air Transportation System Integrated Plan," 2004. Pp 12-14.

on real-time aircraft position, guidelines for enroute spacing by ATC might be reduced, enhancing system throughput. Likewise, with better information on the real time state of the atmosphere across the NAS, users can potentially make better decisions and derive significant operational efficiencies alongside additional airspace capacity.

So far, the work completed with participation by Delta has demonstrated the proper function of two such enabling technologies, TAPS and E-Turb radar, revealing an array of other discoveries and potential applications in the process. But if the systems are to have any relevance and satisfy the need for which they were developed, more work remains.

One major area for further investigation by stakeholder agencies is in the realm of human factors, where a number of fundamental questions present themselves. As background for one such investigation, pilots, dispatchers, controllers, and meteorologists have always looked to radar reflectivity for guidance in avoiding convective hazards. But as technologies such as the E-Turb radar evolve into displaying only the information that is important to the user (i.e. hazards), how should this enhanced data be presented? Basically, what are the implications of previous display methodologies and data hierarchies in designing new display requirements? How, for example, is the depiction of heavy rain in the color red on current radar displays a hindrance to more advanced presentations of weather hazards such as turbulence or hail? What colors and symbols should be associated with turbulence hazards on future generation displays? Also, while it is vital that all users have the same turbulence data to drive decisions, not all users will necessarily view that data in the same way because of the variation in their backgrounds, workloads, and overall missions. A tailored approach in determining how turbulence data get communicated will therefore be essential in achieving an effective, integrated solution. So as technology enables needed and exciting changes, work aimed at answering these questions will be crucial in smoothly shifting the paradigm on how weather information is viewed and, in turn, exploited as an enabler to enhanced safety and additional throughput within the NAS.

Meanwhile, as the state of the art for other sensors advances, other kinds of enhanced threat information will surely proliferate and be presented to many of the same users who are of interest in this discussion. In this context, determining where turbulence stands in the hierarchy of hazards represents yet another human factors challenge. Fundamentally, how does the advent of reliable, high fidelity information on the locations of turbulence hazards, for example, change the way in which turbulence is presented alongside other threats such as traffic, terrain, and icing? How, even, does it change the role of users in the system? Armed with better information, who should be accountable for turbulence encounter decisions given competing demands in workloads and missions? Given all of the enhanced information that will be presented to users, it seems essential that an appropriate place for turbulence be well defined not only in the displays, but also in the

responsibilities of each user, highlighting yet another opportunity for fundamental research.

In fact, issues such as these were viewed as especially important in the work completed at Delta. Many dispatchers commented that in making them accountable to more sources of information, new tools have historically had the unintended consequence of making their jobs more difficult and overwhelming. After designing display and functionality requirements for TAPS information on WebASD, an interesting dichotomy between what dispatchers stated they wanted from even a *trial* system and what they actually used became apparent. Even basic information about TAPS – which dispatchers had previously been enthusiastic about receiving – went largely unused. Many dispatchers were even shown how to view TAPS on WebASD in one-on-one discussions during the course of normal shifts, and gave positive comments concerning the system. But outside these forums, faced with competing demands, workloads and responsibilities, most failed to reference the display at all. So while this highlights the need for an integrated solution for presenting turbulence data at dispatcher workstations, it also begs more research on the broader issue of discerning where turbulence resides in the hierarchy of other data that will be provided by other sensors and technologies.

In referencing real-time data, users will also require some authoritative guidance on appropriate turbulence thresholds in order to form their operational responses. Based on a higher quality dataset, these thresholds will most likely be radically different than the ones currently used. In today's system, just four varieties of turbulence (Light, Moderate, Severe, and Extreme) exist within the vernacular of conventional PIREPs, with very little definition around how users should respond operationally to reports of various intensities. TAPS reports represent objective measurements of rms g, presented as icons referring roughly to the four traditional definitions of turbulence, in accordance with standard terminology for turbulence contained in the Airman's Information Manual (AIM). For example, all TAPS reports with rms g readings between .2 and .29 rms g are categorized as moderate turbulence, and presented as such by a single icon on WebASD. This raises a number of basic questions. Firstly, are the four current levels of turbulence appropriate references for the objectivity and precision of a turbulence reporting mechanism? Perhaps the intensity of automated turbulence reports should be presented as numbers, and if so, how many? Perhaps meteorologists would prefer to see a relatively high number of these levels in order to discern data on a smaller scale, informing better forecasts. Perhaps pilots, controllers, and dispatchers require less definition around turbulence reports, with the various levels serving as drivers for different but complementary operational decisions. As an example scenario, pilots and controllers may use a 7-point scale, making a coordinated decision to ride out areas where "level 3" turbulence is reported, based on considerations such as fuel savings and additional airspace capacity. To enable the forecasting solution, meteorologists, meanwhile, may see the very same turbulence as "level 4" events on a larger scale of 10 or 12. As a

replacement for traditional definitions of light, moderate, and severe turbulence, additional work aimed at ascertaining user specific turbulence thresholds and decision drivers based on turbulence data is therefore needed.

While the above considerations certainly have the industry's attention, the time remaining to maintain the momentum behind these efforts is short. While capable of lending significant resources in the form of an operational platform as well as invaluable guidance based on a real-world, airline perspective, industry partners will nevertheless require direction, support, and resources from stakeholder agencies. Armed with a wealth of experience on these issues and an active and engaged laboratory for such experiments to continue, Delta is perhaps uniquely suited to play a leading role in additional efforts, and welcomes the opportunity to continue its partnership on related research initiatives.

5.3.3 Specific Areas

The following categories are intended only as guidelines. Obviously, there are ways to group such as research levels, disciplines, and strategic objectives.

5.3.3.1 Simulation Models

5.3.3.1.1 A model needs to be developed to simulate new procedures and processes for the Airline Operational Center (AOC) that put more structure around turbulence avoidance with In-situ sensors.

Since in situ turbulence information will radically change the way in which turbulence is viewed and utilized within AOCs, models that optimize the integration of this enhanced data in these environments should be developed.

5.3.3.1.2 A model needs to be developed that will validate the collaboration processes between the three end users (pilots, dispatchers, and controllers) using turbulence as a subset of weather restrictions.

As the JPDO looks toward building comprehensive air traffic management solutions as part of the NGATS, models that incorporate the collaborative response to turbulence restrictions and their impact on, for example, four-dimensional arrival systems will need to be considered.

5.3.3.1.3 An economic model needs to be developed to assess the cost of turbulence avoidance as a subset of weather and other restrictions.

Models to validate the system wide extent of turbulence as a restriction and the resulting impact on economics, capacity and the environment should be developed.

5.3.3.2 End user tools

5.3.3.2.1

One of the major reasons for long lead times in the adoption of new technologies in this industry is the certification process for aircraft hardware and controller systems. Often, by the time the device is in a state to be tested by the end user, it has already met design criteria for certification to avoid unnecessary duplication in the device's development. A common example is an avionics red label part, which often arrives for end user validation relatively late in the certification cycle, rendering user input moot. A similar process occurs in the development of controller systems, where end user inputs are often too late to have any impact.

Fortunately or unfortunately, the airline dispatcher sits mostly at the other end of this spectrum, with less stringent certification requirements for the technologies used in the operations centers. But this is expected to change under the new collaboration model of NGATS, and even now, though much less connected to certification issues, the systems that they use are often very complex and require years to develop. A new flight planning system installed in an AOC, for example, can literally take decades.

5.3.3.2.2 Displays for the end user provide a rich area for research. Examples of areas meriting further work are listed below.

5.3.3.2.2.1 One of the more significant challenges in presenting turbulence and other weather data for the end users centers on the requirement to present data with various latencies. The weather Integrated Product Team (IPT) of the JPDO is working on a 5D weather forecast using 3D space, time, and a probability function, which will likely be displayed to end users along with real time radar/lidar echoes and real-time time-stamped turbulence reports from other aircraft. In addition, Nexrad data might also be presented, which is typically five minutes old. Further work with users aimed at determining appropriate hierarchies for turbulence data of various latencies will therefore be important early in development.

5.3.3.2.2.2 The demands of new systems will provide a real research challenge in presentation schemes. As mentioned earlier, what are the implications of previous display methodologies and data hierarchies in designing new display requirements? How, for example, is the depiction of heavy rain in the color red on current radar displays a hindrance to more advanced presentations of weather hazards such as turbulence or hail?

What colors, symbols and alerts should be associated with turbulence hazards on future generation displays? Also, while it is vital that all users be using the same turbulence data to drive decisions, not all users will necessarily view that data in the same way because of the variation in their backgrounds, workloads and overall missions. Work to answer these questions will be needed.

5.3.3.2.2.3 Human sensory requirements for the different data sets must be integrated in the total end user solution. Most presentation schemes currently involve visual feedback and a discussion of color, layout, and latency schemes as appropriate. Audio schemes for different levels of hazard in the cockpit, such as terrain avoidance, are also prevalent. Certain tactile schemes are used such as control vibration (e.g. Stick Shaker) to warn of an aircraft stall. Since there will be fairly tight collaboration between the three end users, other human sensory requirements might be used for controllers and dispatchers, some of which may be similar to those in the cockpit. Determinations as to which sensory schemes apply to turbulence as a subset of other weather hazards and constraints are therefore needed.

5.3.3.2.2.4 Prioritization of the data is an area requiring substantial research. It is important that prioritized data in the cockpit and other end user systems to meet the demands of the NGATS including safety/security, economics, and environment be used. Fundamentally, how does the advent of reliable, high fidelity information on the locations of turbulence hazards, for example, change the way in which turbulence is presented alongside other threats such as traffic, terrain, and icing?

5.3.3.3 Sensor Development and Preliminary Testing

To enhance airspace capacity and maintain or enhance current safety levels within the National Airspace System (NAS), autonomous sensors will be relied upon extensively in supplying a constantly updated, vast array of data, including weather information, to drive decisions on routing and airspace usage. With better information on the real time state of the atmosphere across the NAS, users can potentially make better decisions and derive significant operational efficiencies alongside additional airspace capacity.

*5.3.3.3.1 **Sensors***

5.3.3.3.1.1 Additional research could be aimed at the development of sensors to differentiate between precipitation and areas of hazard on a large geographic scale. Hazards for detection should include severe turbulence and hail, with the information being used to avoid unnecessary closures of airspace. As mentioned earlier, all three end

users typically avoid areas of red and sometimes yellow, which are merely measure precipitation density rather than hazards.

5.3.3.3.1.2 Using real-time measurements from aircraft as a data source, additional research should be aimed at improving turbulence forecast models

5.3.3.3.1.3Research needs to be continued in the development of sensors required for detection of clear air turbulence, and possible incorporation with other weather sensors. Integration of the various weather sensors is key to the economic health of the airlines

5.3.3.3.2 ***Data Link***

5.3.3.3.2.1 An important corollary to the forecast sensors' research lies in data collection and data compression schemes to minimize data link costs. As mentioned earlier, aircraft sensors are currently inactive on many flights because of data costs. These expenses are a key driver in airline acceptance, and attention to such issues will be important to the success of NGATS as data proliferate. Another area of concern is the use of common aircraft data links whenever possible. It is not desirable to have one data link for weather information and another link for communications. The airlines cannot justify such expenses, and pursuit of a strategy that ignores this consideration will present a roadblock to the success of the NGATS.

5.3.3.4 Collaboration techniques and lower level system integration

One of the key components of NGATS is the collaboration required to increase capacity.[7] An example is using 4D arrival schemes which are designed to maximized use of runway capacity, which requires an onboard system to meet an arrival gate at a certain time. As constraints develop in the system like turbulence and other weather hazards, the Airline Operations Center will have to renegotiate a new arrival time with the ATC command center while consulting with the flight crew.

5.3.3.5 Environmental Requirements

As better operational techniques and procedures around turbulence avoidance are developed, emissions can be reduced through enhanced flight crew responses to turbulence of minimal duration and intensity. This can be accomplished by researching what levels of turbulence are generally acceptable in the daily utilization of airspace and developing procedures and processes that are collaborated with all three end users.

[7] Joint Planning and Development Office. "Next Generation Air Transportation System Integrated Plan," 2004. Pp 12-14.

Appendix A: TAPS In-Service Evaluation: Dispatcher Questionnaire Summary

The following shows all questions and, where applicable, multiple choice responses as presented to the 50 dispatchers who participated in the questionnaire. Tables and graphs show their responses. Notes summarize responses to each question, including mention of any additional comments that dispatchers may have made in their answers.

Dispatcher Questionnaire – Turbulence Procedures, Tools and Techniques

Keeping in mind that all responses will remain anonymous, *please* be as candid yet comprehensive as possible in answering the following.

SECTION 1: General Turbulence Resources and Procedures

1. Besides information provided by the Turbulence Auto PIREP System (TAPS) on the WebASD display, what tools do you utilize to define areas of turbulence while working a shift, how frequently are they referenced, and how do you value the information provided by those tools?

   (For each tool below, respondents had the following choices for their answers)

   Primary Tool: Referenced at least once during any shift
   Secondary Tool: Referenced occasionally or as needed

   Referenced: *Primary* *Secondary* *Rarely* *Never*
   Overall Value: 1 – Occasionally valuable, but usually unreliable or misleading
   2 – Somewhat Valuable most of the time
   3 – Valuable most of the time
   4 – Very Valuable/Essential during any given shift

   <u>Delta Turbulence Forecast</u>

Frequency Referenced

Primary	Secondary	Rarely	Never
45	4	1	0

Overall Value

1 - Least	2 - Somewhat	3 - Most	4 – Essential
6	15	22	7

<u>Alerts from Delta Meteorology</u>

Frequency Referenced

Primary	Secondary	Rarely	Never
29	18	2	1

Overall Value

1 - Least	2 - Somewhat	3 - Most	4 – Essential
3	12	16	19

ADDS PIREPs

Frequency Referenced

Primary	Secondary	Rarely	Never
23	22	5	0

Overall Value

1 – Least	2 – Somewhat	3 – Most	4 - Essential
2	15	25	8

Company PIREPs

Frequency Referenced

Primary	Secondary	Rarely	Never
32	16	2	0

Overall Value

1 – Least	2 – Somewhat	3 – Most	4 - Essential
2	9	16	23

ADDS Graphical Turbulence Guidance (GTG)

Frequency Referenced

Primary	Secondary	Rarely	Never
17	25	6	2

Overall Value

1 – Least	2 – Somewhat	3 – Most	4 - Essential
7	13	24	6

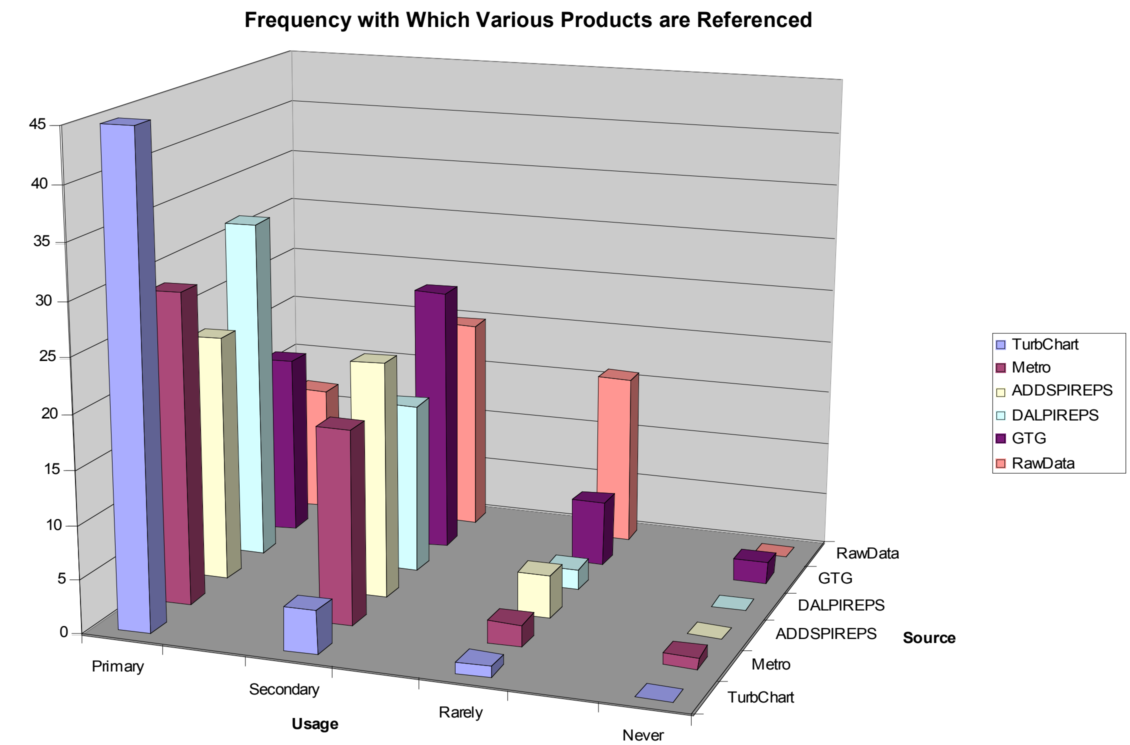
Upper air charts/information (raw data on winds, temps)

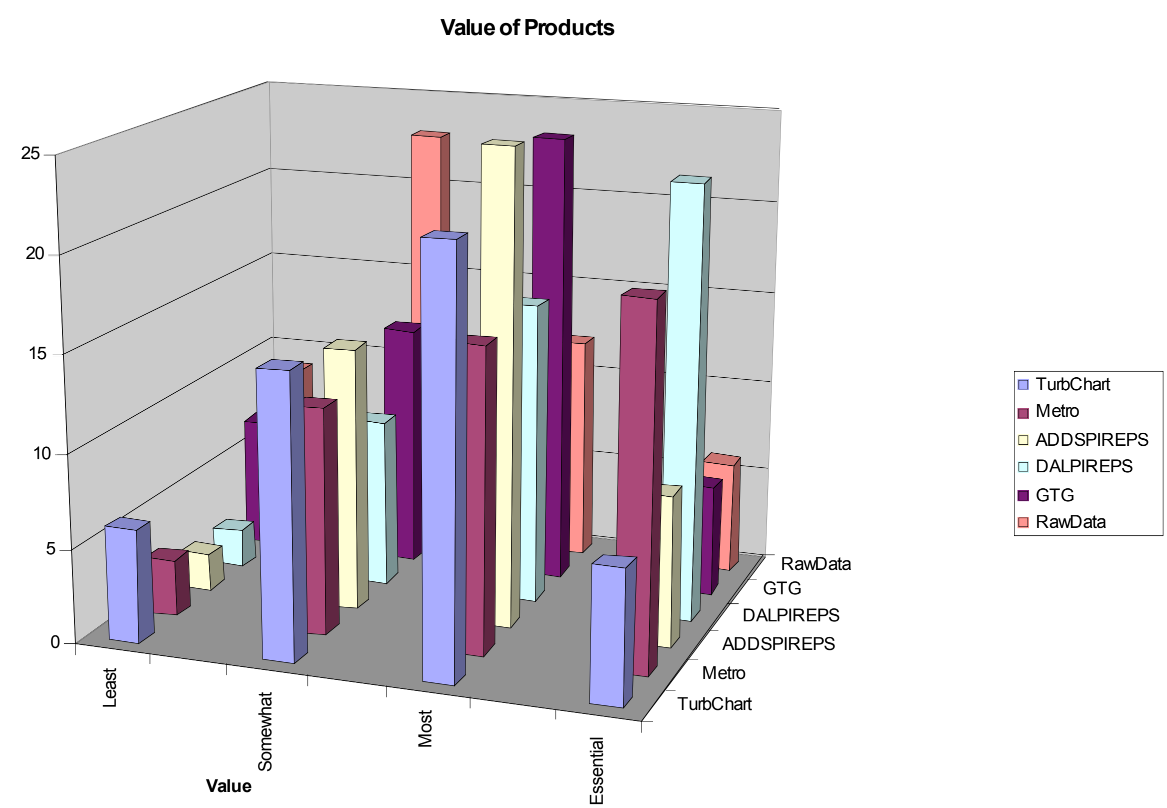
Frequency Referenced

Primary	Secondary	Rarely	Never
12	21	17	0

Overall Value

1 – Least	2 – Somewhat	3 – Most	4 - Essential
9	23	12	6


Frequency with Which Various Products are Referenced
45
40
35
30
25
20
15
10
5
0
Primary
Secondary
Rarely
Never
Usage
TurbChart
Metro
ADDSPIREPS
DALPIREPS
GTG
RawData
Source


Value of Products
25
20
15
10
5
0
Least
Somewhat
Most
Essential
Value
TurbChart
Metro
ADDSPIREPS
DALPIREPS
GTG
RawData

Notes: Data show dispatchers look at many sources for turbulence information, potentially because individual ones or subsets are not accurate enough to make good decisions. Although many acknowledged tremendous subjectivity in PIREPs, responses also show that PIREPs represent the dataset in which the group has perhaps the most confidence – providing at least the locations of turbulence reasonably well. In planning flights, dispatchers rely on forecasts which they feel are only correct a little more than 50% of the time.

2. What minimum level of turbulence prompts you to plan flights above/below/around a given piece of airspace?

   (Respondents had the following choices for their answers)

   LGT CHOP   LGT TURB   MOD CHOP   MOD TURB

Dispatcher Responses	
Light Chop	1
Light Turbulence	3
Moderate Chop	28
Moderate Turbulence	18

Notes: Dispatchers mainly tend to make decisions based on Moderate Turb/Chop. Light Turb/Chop is not considered a factor for planning. Interestingly, this contrasts with results from pilots, who tend to use Light Turb/Chop as a trigger to act.

3. Do you find a general disparity between the level of turbulence contained in a forecast for a given area and the levels of turbulence actually reported by pilots within that area (e.g. Do turbulence forecasts tend to be conservative in nature, forecasting levels of turbulence that are higher than may actually be present, or is it the other way around)?

   (Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
Too conservative	39
Too conservative – but forecaster Dependent	13
Too conservative – but understandable due to potential for severe turbulence	1
Too conservative – timeframe for forecast too long	5
Varies with forecaster and area	3
Forecasts underestimate turbulence	1
Forecasts are on target	0

a. If so, how does this affect your practice of turbulence avoidance in flight planning (Do you account for the disparity in turbulence forecasts and actual conditions)?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
Account	38
Account – Need other data	33
Account – Size of Forecast Area	2
Account – Lack of PIREPS	4
Ignore	6

b. More generally, how often (as a percentage) would you estimate that forecasts of turbulence are accurate?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	*Percent*	*Std Dev*
All Forecasts	58	18
Delta Turb Forecast	57	27
Delta Metro Alerts	64	14
ADDS PIREPS	76	10
Graphical Turb Guidance	67	15
SIGMETS	15	7

<u>Notes</u>: *The group generally feels that forecasts are conservative, meaning forecasters predict turbulence of greater intensity than what is actually reported. Reasons offered for this approach included a desire by meteorologists to protect themselves from any liability. A good example of doomsday forecasts occurs in Japan, where the culture is very sensitive due to several high profile accidents. However, dispatchers are conscientious in accounting for this disparity by cross checking other sources, especially ones in which they have a higher confidence.*

The overall average for forecast accuracy was 58% with a standard deviation of 18. The group also listed a subset of sources it uses the most, which were similar to the overall average except for ADDS PIREPS at 76% and SIGMETS at 15%. Both of these were a much smaller sample size, since only a few dispatchers listed them as sources outside the options listed in the questionnaire list. In any case, it's clear that there are no very precise tools for dispatchers to use in making good decisions.

4. What kind of role do you play in avoiding encounters with ***convective*** turbulence?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Preflight

Type of Action	
Flt Plan Remarks - Summary	22
Plan Around Mod when Possible	30
Less Active	4
More Active	15
Most Active	4

Notes: The dispatchers appear to be very active in the Preflight phase, making notes in the Remarks section of the Flight Plan, and routing based on forecasts of Moderate turbulence as baseline activities. Still, these decisions are based on an array of data without a huge confidence level (e.g. in the range of 60%).

Climbout

Type of Action	
ACARS PIREPS to crew	11
Contact only with big changes	8
Less Active	30
More Active	8
Most Active	0

Notes: The dispatchers seem to take a less active role in the climb phase, generally taking action only in cases of major changes based on PIREPS or Forecasts. They are also less likely to send ACARS messages to the crew due to crew workload.

Enroute

Type of Action	
Give Input on best Flight Level	8
ACARS PIREPS, AIRMETS, SIGMETS	23
Strategic Advice on Deviations	24
Less Active	3
More Active	21
Most Active	8

Notes: By monitoring more tactical information such as PIREPs and updated Convective SIGMETs, the dispatchers appear more active in this phase, and are much more likely to send ACARS messages given crew workloads.

Descent

Type of Action	
Same as Climbout	13
ACARS Low Level Wind Shear	9
ACARS ITWS Info	4
Contact only with big Changes	7
Less Active	23
More Active	10
Most Active	1

Notes: *The dispatchers treat this phase similar to the Climb with a less active role. They will still alert the crew to significant changes, which can be fairly subjective.*

a. For flights operating near thunderstorms in terminal areas, how much of a role do/can you play in guiding turbulence avoidance?

Type of Action	
ACARS Wind Shear & Other Hazards	17
Monitor ITWS & ACARS as Needed	5
Major Role	8
Constrained by ATC, Therefore Minimal	24
Null	2

Notes: *Given significant constraints due to ATC and high crew workloads, the dispatchers take a less active role in the terminal area, sending an ACARS message only if they feel a definite hazard exists (e.g. wind shear or reports of severe).*

b. In these same areas, are reports of turbulence valuable to you as a dispatcher?

Dispatcher Responses	
Yes	49
No	1

i. If so, how long do you view these reports to be valid?

Average Minutes	Std Dev
40	26

Notes: *The duration for the validity was somewhat subjective based on a lack of knowledge.*

c. Would you find information concerning the actual turbulence hazard posed by an area of reflectivity (usually in the vicinity of convection) to aircraft you are handling helpful?

Dispatcher Responses	
Yes	45
No	5

<u>Notes</u>: *These responses were based on the group's fairly rudimentary understanding of the E-Turb radar, and most also noted that they would want more training on how the system worked.*

A common mistake in all phases of flight was to tightly correlate levels of radar reflectivity with the levels of turbulence that might be expected, an approach which the E-Turb calls into question. Several comments were made on the importance of human factors in the presentation of the new products, and most dispatchers felt they would need more training on the integration of the various new products being considered.

5. What kind of role do you play in avoiding encounters with ***clear air*** turbulence?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Preflight

Type of Action	
Flt Plan Remarks - Summary	28
Plan Around Mod (or greater) when Possible	33
Less Active	3
More Active	16
Most Active	6

<u>Notes</u>: *The dispatchers appear to be very active in the Preflight phase, making notes in the Remarks section of the Flight Plan, and routing based on forecasts of Moderate turbulence as baseline activities. These decisions are again based on an array of data without a huge confidence level (e.g. in the range of 60%, similar to Convective). The group also felt Clear Air phenomena were significantly more difficult to predict and locate.*

Climbout

Type of Action	
Advise Flight Levels	12
ACARS PIREPS	13
Contact only with big Changes	8
Severity Dependent	3
Less Active	24
More Active	6
Most Active	0

<u>Notes</u>: The dispatchers seem to take a less active role in the climb phase, generally taking action only if they see major changes based on PIREPS or Forecasts. Again, they are also less likely to send ACARS messages to the crew because of crew workload.

Enroute

Type of Action	
Advise Changes	29
ACARS PIREPS AIRMETS SIGMETS	33
Less Active	1
More Active	28
Most Active	3

<u>Notes</u>: The dispatchers appear more active in the Enroute phase by monitoring more tactical information such as PIREPS and updated AIRMETS/SIGMETS. They are also much more likely to send ACARS messages in the cruise phase considering reduced crew workload.

Descent

Type of Action	
Give best Estimate	17
ACARS Low Level Wind Shear	7
Contact only with big Changes	8
Less Active	23
More Active	11
Most Active	0

<u>Notes</u>: The dispatchers treat this phase similar to the Climb with a less active role, while still alerting the crew to significant changes which can be fairly subjective. They also tend to give more information than with convective phenomena, since they feel that crews have much less ability to detect clear air turbulence.

a. For flights operating near clear air phenomena in terminal areas, how much of a role do/can you play in guiding turbulence avoidance?

Type of Action	
Reports from Previous Flights	24
Based on Pilot Request	0
ACARS SIGMETS PIREPS –Mod & greater	15
ACARS ITWS CIWS	1
Less Active	22
More Active	11
Most Active	0

<u>Notes</u>: The dispatchers take a less active role in the terminal area, but it is more active than with convective activity since the crews have a harder time detecting clear air. Still, they feel that ATC restricts them to a great degree, but will send an ACARS message if they feel a definite hazard exists (e.g. wind shear or reports of severe).

b. In these same areas, are reports of turbulence valuable to you as a dispatcher?

Dispatcher Responses	
Yes	50
No	0

i. If so, how long do you view these reports to be valid?

Average Minutes	Std Dev
62	38

<u>Notes</u>: Interestingly, many felt the reports would still be valid 50% longer than convective phenomena, but most commented that this was based on mountain waves and jet stream CAT, which tend to endure in location and intensity. This might not be true much of the time, especially in the terminal area.

6. Do you feel that there is an altitude threshold below which flight crews either already are or should be operating tactically with little real-time input on turbulence from the dispatcher, and if so, what is that altitude?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
Yes	42
Below 10K feet: 34 Below 5K feet: 8	
No	8

<u>Notes</u>: Most dispatchers feel pilots are reacting mainly to ATC in the Terminal area (defined primarily as below 10,000 feet in the descent phase), with little input from dispatch. By listening to reports over the ATC frequency, many commented that pilots have the same or better information than the dispatcher. Workloads are also much higher in these areas, so there is little opportunity for the dispatcher to provide timely information more relevant than that available to the crews. Exceptions include times when the dispatcher receives a report of severe turbulence or low level wind shear, which usually triggers an ACARS message. Still, it is suspected that sending messages such as these represents a regulatory induced response, since these reports are usually also being broadcast over ATC frequencies.

7. When *planning* flights around a given piece of airspace due to turbulence, what steps do you take in coordinating a re-route or recommending an alternate altitude?

   (Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Steps Taken	
Contact Delta Metro	23
Review PIREPS	30
Provide Summary Flt Plan Remarks	32
Assess Turbulence Severity	14
Assess Forecasts	11
Assess Fuel Tradeoffs	11
File Next Optimal Route and/or Altitude	13
Provide Next Best in Flt Plan Remarks	16

<u>Notes</u>: Most dispatchers confirmed that PIREPS, Forecasts, and Delta Meteorology are the primary sources for making their decisions. There is usually very little direct dialogue with the pilots in the preflight phase. The dispatcher either plans around the area on the original flight plan without dialogue with the crews, or provides recommendations in the Flight Plan Remarks leaving enroute tactical decisions to the crew as conditions evolve. One wonders whether the people involved have such a lack of good data that they only attempt to offer broad guidelines in the hope that more tactical information gained during the flight will provide the best information. This begs the question of whether the overall plan is being optimized based on company goals.

8. Versus alternate altitude recommendations, how often (in terms of number of instances per year and a percentage) is it necessary for you to *personally initiate* re-routes (due to turbulence) for aircraft that are already enroute?

   (Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Average Percentage	Std Dev
6	5

   <u>Notes</u>*: This excludes tactical deviations for convective activity. Even though many in the research community perceive that dispatchers initiate a lot of reroutes to avoid turbulence, the data show that this happens very seldom. It again underscores the importance of an integrated solution whereby those closest to the phenomena (pilots and ATC) are in the loop, looking at similar information for better tactical decisions.*

9. How often do areas of turbulence that were *not* forecast (but confirmed by PIREPs or other means) result in changes to preflight route planning?

   (Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Average Percentage	Std Dev
7	6

   <u>Notes</u>*: This question was misunderstood by several dispatchers, but in many cases, their notes clarified their interpretation and provided some valuable insights. Generally, the dispatchers felt the different forecasts tended to overstate the existence of turbulence in both intensity and area, so it was unusual to have PIREPS outside these forecast areas. If they did find PIREPS outside the forecast area, they would generally plan around it. Most indicated a valid PIREP would trigger them to change routing 80% to 100% of the time. It is noteworthy that PIREPS drive a lot of decisions, but the data mined at Delta show that PIREPS are highly subjective, often failing to correlate to the TAPS based g load thresholds for various levels of turbulence.*

10. Based on pilots' tactical decisions and guidance from ATC in avoiding turbulence on a day to day basis, would you say that your role today tends to be more reactive or proactive when collaborating with flight crews to avoid areas of turbulence during the enroute portion of a flight?

    (Answers to this question were fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
Proactive	29
Reactive	21

Notes: Most qualified their answers with the caveat that their approach depends heavily on the information available to them, with many noting that they would be more proactive if they had better information to pass to the crews. Some also commented that by making the dispatcher accountable to new and better information, the advent of new tools has had the unintended consequence of making their jobs significantly more difficult and sometimes overwhelming, underscoring the importance of human factors in presenting new data.

SECTION 2: Scenario-based Questions

(Answers to these questions were strictly fill-in, and those inputting the data developed the categories below to account for responses. To make sense of the answers, many dispatchers wrote that they would advise the crew to explore a variety of actions, so all possible options have been included.)

Scenario A

11. A Delta B757 flight crew makes a conventional PIREP via ACARS of "moderate chop" during cruise at FL330 over southwestern Utah, and descends to FL270 for a better ride. Due to traffic, the flight is unable to climb again for 30 minutes, devastating fuel consumption vs. what had been planned at FL390. Recent TAPS reports made in the vicinity (see Illustration for Scenario A in the Appendix) confirm the presence of what flight crews would term mostly light, occasional moderate turbulence, but also show the dimensions of the turbulence to be only 80 nautical miles long. If you were handling a flight about to enter this area (e.g. DAL1276, as depicted in the Illustration), and were planning flights that would transit this area later on, how would you handle with this information?

Dispatcher Action/Recommendation	
Higher Altitude	10
Lower Altitude	9
Reroute No Altitude Change	3
Reroute With Altitude Change	0
Stay the course	30
Advise Crew of conditions	47

Notes: All the dispatchers felt the TAPS information provided was valuable enough to be proactive in advising the crew of Delta 1276 of the scenario in Question 10. 30 of them would recommend that crews stay the course with the seat belt sign ON. 9 would recommend a lower altitude due to possible moderate turbulence, with an advisory that the crew check the impact on fuel before descending. 10 would recommend a higher altitude if weight and ATC permitted, so as to avoid the moderate turbulence and

possibly avoid a fuel problem. 3 would reroute if fuel considerations allowed them to do so. Overall, the dispatchers became very involved with reasonable alternatives because of the better information available to them.

Scenario B

12. While settling in for a shift, you observe a TAPS report of moderate turbulence at FL330 over southern Colorado (see Illustration for Scenario B in the Appendix). Just 3 minutes behind the aircraft that made the report, having been on the exact same route and at exactly same altitude, is another aircraft (of the same type and approximately the same weight) also capable of making TAPS reports. You observe, however, that this aircraft made no electronic report of turbulence while transiting the airspace where the first aircraft made a report. If you were handling a flight about to enter this area, and were planning flights that would transit this area later on, how would you handle this information?

Dispatcher Action/Recommendation	
Nothing	3
Advise & Request Ride Report	46
Assume System Failure	1
Gather Other Information	33

<u>Notes</u>: *46 dispatchers wrote that they would take action by advising other crews and requesting ride reports to validate the reports. 3 wrote that they would ignore it primarily because it was in an area of convective activity (the light Nexrad echoes some miles distant from the reports were not intended to connote an area of convection, however) where turbulence can change quickly based on storm movement. Only one assumed a system failure, but even this dispatcher would opt to get more information to validate the decision. Overwhelmingly, the dispatchers paid attention to the TAPS reports and advised the crew of the potential turbulence. They also focused on the area as one of concern and attempted to gather more data to make good decisions.*

Scenario C

13. While looking at a WebASD screen showing TAPS reports, you notice an aircraft on the Falcon arrival (northeast of DIRTY) make a TAPS report of severe turbulence in the vicinity of convection at 16,000 feet (see Illustration for Scenario C in the Appendix).

    c. If the last flight you were handling during the shift were an aircraft along the same flight path, but 3 minutes behind the aircraft that sent the report, how would you handle this information?

Dispatcher Action/Recommendation	
Nothing	3
Advise Crew	47

<u>Notes</u>: 47 out of 50 would advise the crew immediately. Even though the report is located near only very light reflectivity on the north side of the cell, 3 of the dispatchers would not advise the crew only because they felt time was limited and the crew would be avoiding the area anyway based on radar echoes presented on their airborne weather radar (which NASA flight tests and other data at Delta show might not correlate to the severe turbulence). Most agreed the message would be limited and to the point due to high workloads and limited time for crews to react.

b. If you were handling an aircraft 7 minutes behind the aircraft that sent the report, how would you handle this information?

Dispatcher Action/Recommendation	
Nothing	1
Advise Crew	49

<u>Notes</u>: 49 out of 50 would advise the crew immediately. One of the dispatchers would not advise the crew only because he felt the crew would be avoiding the area based on the radar reflectivity. Most agreed the message would be more detailed with more time available to react.

c. If you were handling an aircraft 15 minutes behind the aircraft that sent the report, how would you handle this information?

Dispatcher Action/Recommendation	
Nothing	1
Advise Crew	49

<u>Notes</u>: 49 out of 50 would advise the crew immediately. One of the dispatchers would not advise the crew only because he felt the crew would be avoiding the area based on the radar reflectivity. Most agreed the message would comment on the movement of the convective weather compared to the time of the original report. More specifically, the dispatchers wrote that they would be least forceful with their recommendation since the cell near the report might have moved out of the approach corridor.

d. If your workload was high due to holds, diversions and other constraints related to convection in the terminal area, how would this affect your ability to look at WebASD, and, if able, process a TAPS report of severe turbulence as outlined above?

Dispatcher Action/Recommendation	
Consult WebASD & Act	10
Consult WebASD but Not enough time to Act	12
Not enough time to pull up WebASD	28

Notes: With a high workload based on the present WebASD display and the attendant problems of smoothly integrating the information on their desktops, only 10 dispatchers would take action on the reports. Another 12 would consult the display but would probably take no action due to a high workload. Finally, 28 would not consult the display at all.

e. If there were lots of other TAPS reports of turbulence in the vicinity, how would this affect your ability to look at WebASD, and, if able, process a report of severe turbulence as outlined above?

Dispatcher Action/Recommendation	
Take Action because of more reports to confirm	37
Take No Action because of WebASD issues	13
Remove Screen because of WebASD issues	3

Notes: 37 out of 50 would advise the crew immediately, while 13 would take no action and 3 would remove the screen primarily because of information overload.

Workload issues seem to be the common problem in Questions 13d & 13e, with the most important drivers related to the presentation of the data. Respondents seem particularly concerned with issues such as integration of the data, priority schemes and display formats, all related to human factors.

It is important also to keep in mind that Question 13 was designed for responses in the terminal area, which poses the most demands on this type of system, since there is far less room for maneuvering by the crew and requires a lot of focus on the part of the dispatcher. Typically, the enroute environment allows more time for the dispatcher to react and the crews usually have more options because of fewer constraints. In the few cases where the dispatcher did not advise the crew, it was because they felt the crews were aware of the convective activity and would avoid the strong cells if possible.

One interesting point in this question is that dispatchers seem to confirm the belief that reflectivity on radar screens (e.g. red) correlates closely with Moderate to Severe turbulence. As noted elsewhere, however, this correlation has been brought into question based on the work done with the E-Turb radar, which has often revealed the presence of strong turbulence in areas of little or no reflectivity, and relatively smooth air in areas of high reflectivity.

14. In general, do you feel that real-time, objective information on turbulence around areas of convection would enhance your ability to perform your duties?

    (Answers to this question were fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
Yes	43
No	7

    Notes: *Respondents also consistently commented that radar reflectivity was the prime source of information for avoiding turbulence near thunderstorms, and 7 of the 50 felt that the radar was the only source used by the crews in a convective environment.*

15. Do you feel that there is a greater need for real-time, objective information on clear air turbulence vs. convective turbulence?

    (Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
Yes	49
No	1

    Notes: *Most respondents felt TAPS data would be more valuable when used in an area of Clear Air Turbulence, since there were no other valid sensors on the aircraft. One felt TAPS information would be of no value, but offered no explanation.*

SECTION 3: Personal Background

(The following set of questions was asked to understand individual responses to various questions, and to see if there was some correlation between prior experiences and individual approaches to turbulence. Since these experiences seemed not to be a factor, no summary of responses has been included.)

1. How long have you been a dispatcher?
2. How long have you been a dispatcher with Delta?
3. As a Delta dispatcher, do you work an International desk or a Domestic desk?
4. Please list any pilot certificates and ratings held.
5. Is there anything else about your background that might be helpful in understanding your responses to this survey (e.g. background as a professional meteorologist , previous occupations etc.)?
6. Have you used the TAPS information/reports on WebASD?
7. How often did you use the TAPS information (have the WebASD screen available)?
8. When was the last time you used TAPS?
9. When were you introduced to TAPS?

10. When was the most recent time you were trained on TAPS?
11. Have you read the TAPS user guide?
12. Have you handled a flight where an airframe inspection was required due to the captain's assessment of turbulence?
13. Have you handled a flight where there was an injury due to turbulence?

SECTION 4: Historical uses of the Turbulence Auto PIREP System (TAPS) on WebASD

The following questions relate primarily to any prior uses of TAPS information on WebASD that you may recall. If you cannot recall any instance in which you used the Turbulence Auto PIREP System, answer each question as applicable.

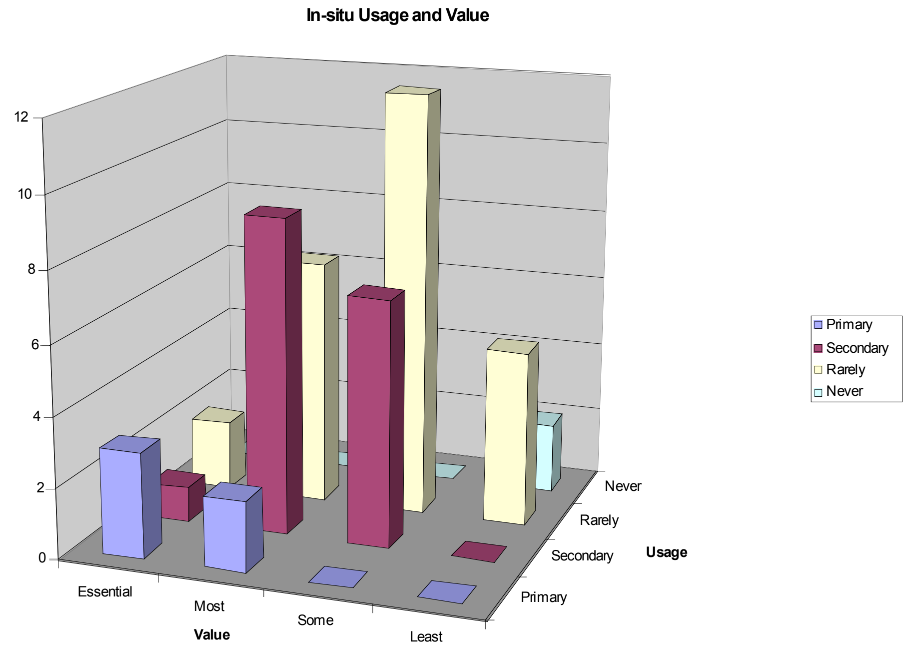
<u>Important Note</u>: *Although the feed of TAPS reports on WebASD had been available to dispatchers until about June of 2006, active project work and support for the technologies ended in January of 2006. As a result, on average, dispatchers stated that they had last used TAPS more than 9 months prior to sitting for this questionnaire.*

16. During the period in which it was available, how would you categorize your use of the information provided by TAPS reports on WebASD?

(Respondents had the following choices for their answers)

Referenced: *Primary* *Secondary* *Rarely* *Never*
Overall Value: 1 – Occasionally valuable, but usually unreliable
2 – Somewhat Valuable most of the time
3 – Valuable most of the time
4 – Very Valuable/Essential during any given shift

	Primary	Secondary	Rarely	Never
4 – Essential	3	1	2	0
3 – Mostly valuable	2	9	7	0
2 – Somewhat valuable	0	7	12	0
1 – Least valuable	0	0	5	2



Notes: *Although other questions clearly show that dispatchers want more objective information on turbulence, their historical use of TAPS was not as high as some of the sources with which they were more comfortable. Still, over time as they gained confidence in the system, many commented that they learned to appreciate the objective, real time value of TAPS data. PIREPS and TAPS data were primarily used to validate the forecast in the planning process, and also in the more tactical decisions once the flight was dispatched.*

Please explain why you reference TAPS as indicated here (include system advantages, shortcomings etc.).

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
Con - Not Integrated in Graphical Flt Following	12
Con – Threshold seems high & Insufficient Reports	3
Pro – Objective information	11
Pro – Timely information	7
Con – Glitches using WebASD	16
Pro – Good reference for airframe inspections	2
Pro – Good Reference for Turbulence in General	9
Con – Insufficient Coverage & Reports	12

Notes: *One of the major reasons for not using the TAPS data was the difficulty that the group had in using the data. 16 dispatchers commented on problems accessing the data, and 12 commented that they would use it more frequently if it were*

integrated into their Graphical Flight Following (GFF) System. 11 specifically commented that they really liked the objective nature of the data versus the subjective nature of PIREPS. Although not specific in nature, others indicated a similar attitude in discussing TAPS data as a valid verification tool for forecasts and PIREPS.

17. Via the following metrics, please give as many examples as possible of times *within the last year* when real time, objective TAPS information either was helpful or could have been helpful in performing your duties?

    e. Turbulence encounters avoided

    (Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
None	25
Possibly Once	3
Possibly Twice	4
Possibly Several	18

Notes: 25 could not remember or project a situation where the data would have helped. 25 had at least one occasion where the data would have helped, and 18 had several or more occasions. Many, however, found the term "turbulence encounter" too vague to craft a meaningful response, but put down an answer anyway.

    f. Airframe inspections avoided

    (Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
None	41
Possibly Once	5
Possibly Twice	3
Possibly Several	1

Notes: Although 41 could not remember or project a situation where the data would have helped, it is important to note that airframe inspections are not a common occurrence. When one does happen, however, it often creates a set of equipment issues that ripple through the system.

c. Reductions in traffic flow disruptions

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
None	42
Possibly Once	2
Possibly Twice	1
Possibly Several	5

Notes: *Comments indicated that dispatchers are unclear on how ATC and pilots will actually use the data in the system, but were open to the possibilities.*

d. Other benefits (e.g. confidence in flight situation, workload etc.)

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
None	21
Possibly Several	9
Useful check for PIREPS & Forecasts	21

Notes: *There was some difficulty for the dispatchers in trying to speculate about a hypothetical (i.e. recalling instances when TAPS data might have been of benefit versus actual situations encountered). This was especially true for those dispatchers who had not used the data frequently. Still, use of the data as a crosscheck against PIREPS was a recurring theme.*

18. Is WebASD a useful/viable platform for you to reference TAPS information?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
Yes	27
No	23

Notes: *While 27 felt the display was adequate, most also wrote that they would prefer an integrated display.*

a. If not, how would you suggest that TAPS data be presented at your workstation?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
Put TAPS into in-house display	28
Eliminate WebASD access glitches	3
More input from Delta on Displays	2
Put Mod/Severe Reports in Dispatcher Queue	1
Provide different screen	2
Quicker sign-in	1
N/A	10
Null	5

Notes: *Integration of TAPS data into the Delta flight following display was mentioned as perhaps the best option.*

19. As presented on WebASD, TAPS reports can be scaled to assess the impact of the same turbulence on different airframes.

a. Have you used this feature?

(Answers to this question were fill-in)

Dispatcher Responses	
Yes	48
No	2

Notes: *Most commented that the feature was not very user-friendly.*

b. Do you feel that scaling either is or could be helpful?

(Answers to this question were fill-in)

Dispatcher Responses	
Yes	42
No	3
Null	5

Notes: *While most felt the feature* could *be helpful, the key is to make it easy to use.*

c. Is the process to conduct the scaling straightforward, and if not, how do you feel this feature could be made easier?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
Yes	7
No	6
Null	37
Put TAPS into GFF	1
Make it as simple as Pointing & Clicking	2

20. TAPS on WebASD is also capable of presenting real time turbulence advisories to the dispatcher when TAPS reports are made along the routes of specified flights.

a. Have you used this feature?

(Answers to this question were fill-in)

Dispatcher Responses	
Yes	16
No	34

b. Do you feel that these advisories either are or could be helpful?

(Answers to this question were fill-in)

Dispatcher Responses	
Yes	50
No	0

c. Is the process to establish advisories for specified flights straightforward, and if not, how do you feel that this feature could be made easier?

(Answers to this question were fill-in)

Dispatcher Responses	
Yes	9
No	9
Null	31
Put TAPS into GFF	2

21. How many of your flights would you estimate deviate from the flight planned altitude at least once *during cruise flight* due to turbulence?

(Respondents had the following choices for their answers)

<20%   20-39%   40-59%   60-79%   80-100%

Percent	*Dispatchers*	*Mid Point*
< 20	16	15
20-39	20	30
40-59	11	50
60-79	3	70
80-100	0	90
Weighted Average		**32 %**

a. Once off of the flight planned altitude, how long on average do they remain at the new altitude?

(Respondents had the following choices for their answers)

<20 minutes
20-39 minutes
40-59 minutes
60-90 minutes
The remainder of cruise flight

Minutes	*Dispatchers*	*Mid Point*
< 20	6	15
20-39	24	30
40-59	5	50
60-90	5	75
Remainder of Cruise	10	60
Weighted Average		**41 Minutes**

Notes: A high number of dispatchers (34) feel that altitude changes are frequent occurrences, and although 16 show < 20%, even this is significant. 44 dispatchers report that when an altitude change is initiated, the duration can last from 20 minutes to the duration of the cruise portion of the flight. Interestingly, the pilots' responses show that dispatchers still may underestimate how often this happens.

Perhaps the most important consideration in all this is that having 32% of all flights deviate from the optimum altitude for an average of 41 minutes results in a large economic cost in additional fuel burn.

22. Given the dynamic nature of turbulence, what other types of turbulence information (beyond TAPS) do you feel would be helpful either in avoiding or enhancing operational awareness of turbulence in a given piece of airspace (e.g. better forecasts etc.)?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
More Feedback from Crews	9
More Feedback from ATC	3
Better Forecasts	30
More Specific Data	7
ADDS for International Flights	3
More information on Temp & Wind	3
More ITWS sites	2
Null	4

Notes: *Better forecasts are a recurring requirement for the dispatchers, especially with respect to more strategic planning (i.e. 1 to 6 hrs).*

23. Do you have any other recommendations to enhance the operational relevance of TAPS?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
No	16
Wider coverage & equipage	6
Reinstate availability	3
Put TAPS into GFF	12
Make WebASD more user friendly	12
Ability to pass reports quickly	4
Put Mod/Severe reports in Message Queue	2

24. Have you passed information from TAPS reports to aircraft that you are handling? If so, during what phase of flight of the aircraft did you pass the information and what was it used for (situational awareness of turbulence, routing decision, severe load confirmation, etc.)?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
Yes	23
No	27
Flight Planning	3
Enroute Advisories	19
Correlate PIREPS	0
Confirm Turbulence	3

<u>Notes</u>: *Most were used as advisories for flights that were already enroute as an aid to situational awareness. Others were used for flight planning and to confirm the presence of turbulence.*

25. Have pilots requested TAPS information from you?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Dispatcher Responses	
Yes	6
No	44

<u>Notes</u>: *The pilots were originally briefed on the TAPS program after the initial installation of TAPS in 2004, but their training concentrated more on the E-Turb Radar. Therefore, it is not surprising that that they would not request this data. In the questionnaires administered to pilots, however, crews were very receptive to receiving such information.*

26. Have you had a pilot report turbulence around the same time that his aircraft produced a TAPS report? If so, on average how does the information in the manual pilot report compare to the TAPS report?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses. In making sense of the following, of the 20 dispatchers who did *notice a pilot report turbulence around the same time as a TAPS report, many individuals wrote that they had witnessed instances where (1) the intensity reported by TAPS was similar to the intensity reported by the pilot, (2) the intensity reported by TAPS was greater than indicated by the pilot, and (3) vice versa. All of these accounts were included in the table).*

Dispatcher Responses	
No	30
Yes	20
Yes TAPS>PIREPS	6
Yes TAPS<PIREPS	15
Yes TAPS=PIREPS	7

27. In your opinion, which is more timely: a manual report of turbulence from a pilot or a TAPS report?

(Answers to this question were fill-in)

Dispatcher Responses	
TAPS	38
PIREP	12

28. In your opinion, is a TAPS report more accurate in terms of location and severity of the encountered turbulence than a manual pilot report of turbulence?

(Answers to this question were fill-in)

Dispatcher Responses	
Yes	45
No	5

29. Have you used information from a TAPS report during discussions with pilots regarding a request for a Severe Loads Inspection?

(Answers to this question were fill-in)

Dispatcher Responses	
Yes	3
No	47

30. Have you looked at TAPS reports to assist in planning routes for flights?

(Answers to this question were fill-in)

Dispatcher Responses	
Yes	19
No	31

   a. Do you think that TAPS reports could be used to assist in route of flight planning?

   (Answers to this question were fill-in)

Dispatcher Responses	
Yes	44
No	6

31. What is the information you want immediately available in a TAPS report? Flight Number? Encounter Location (Lat/Long)? Encounter Altitude? Turbulence Severity Metric? Aircraft Type? Time of Report? Aircraft Weight? Aircraft Speed? Severe Loads Flag/Maintenance Flag?

(Most respondents circled their answers as they appeared in the body of the question, but were otherwise fill-in)

Dispatcher Responses	
Flt Number	39
Location	41
Altitude	48
Severity	46
Time of Report	46
A/C Type	48
A/C Weight	19
A/C Speed	17
Maintenance Flag	24

32. What TAPS filtering functions are important to you? By time? By severity? By altitude? By geography?

(Most respondents circled their answers as they appeared in the body of the question, but were otherwise fill-in)

Dispatcher Responses	
Time	41
Severity	43
Altitude	44
Areas	36

Dispatcher Questionnaire Appendix

Illustration for Scenario A

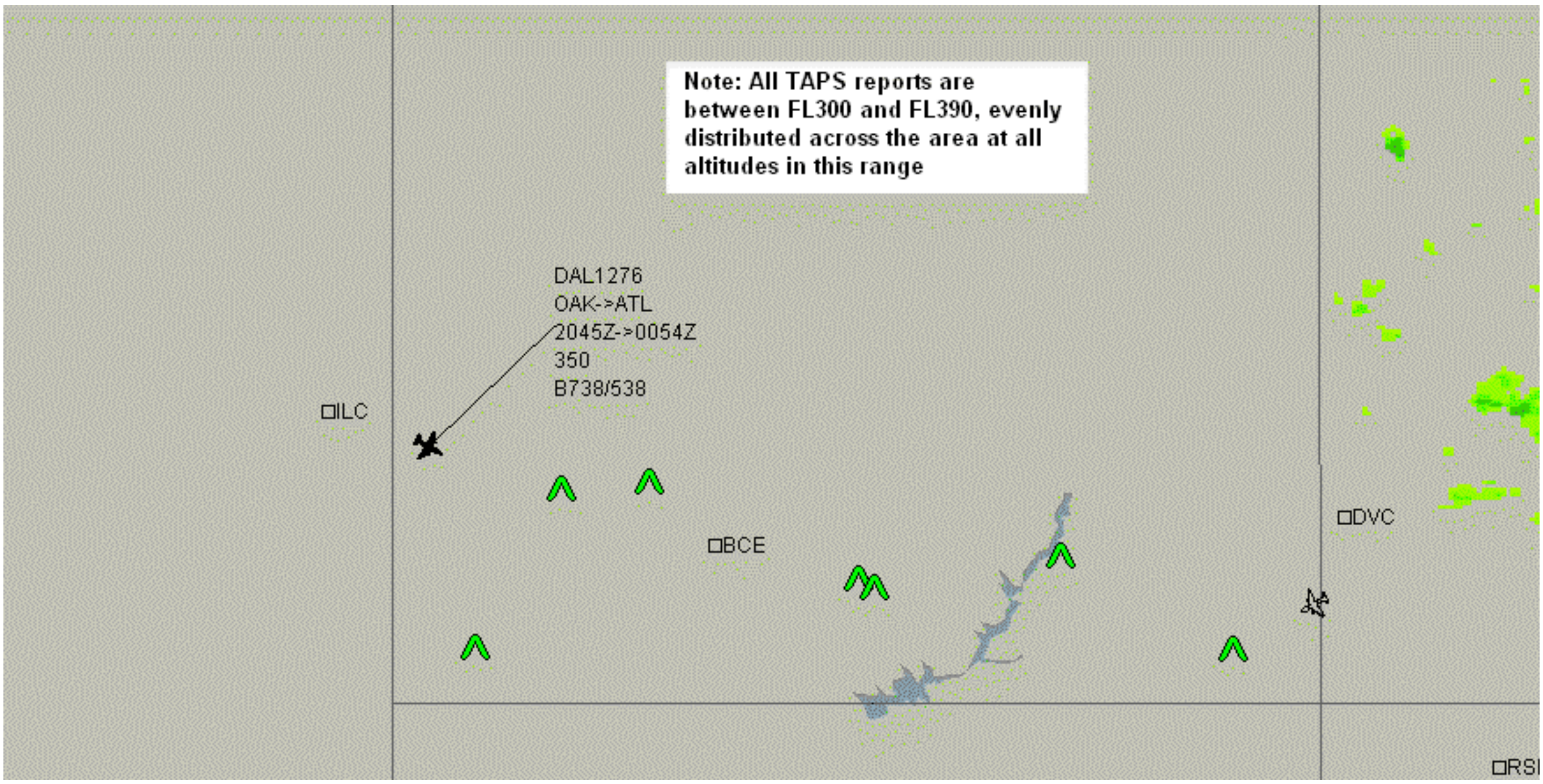


Illustration for Scenario B

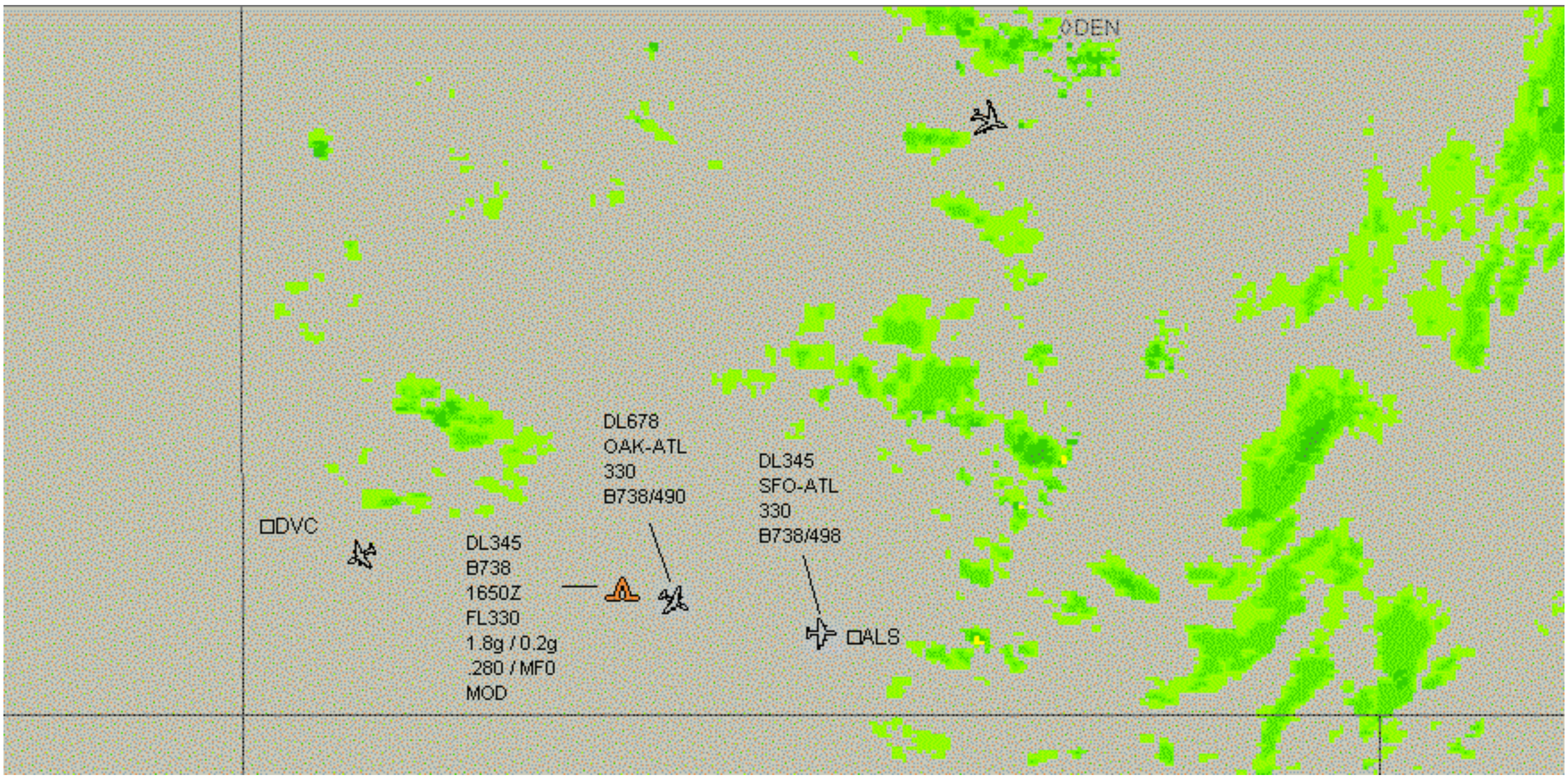
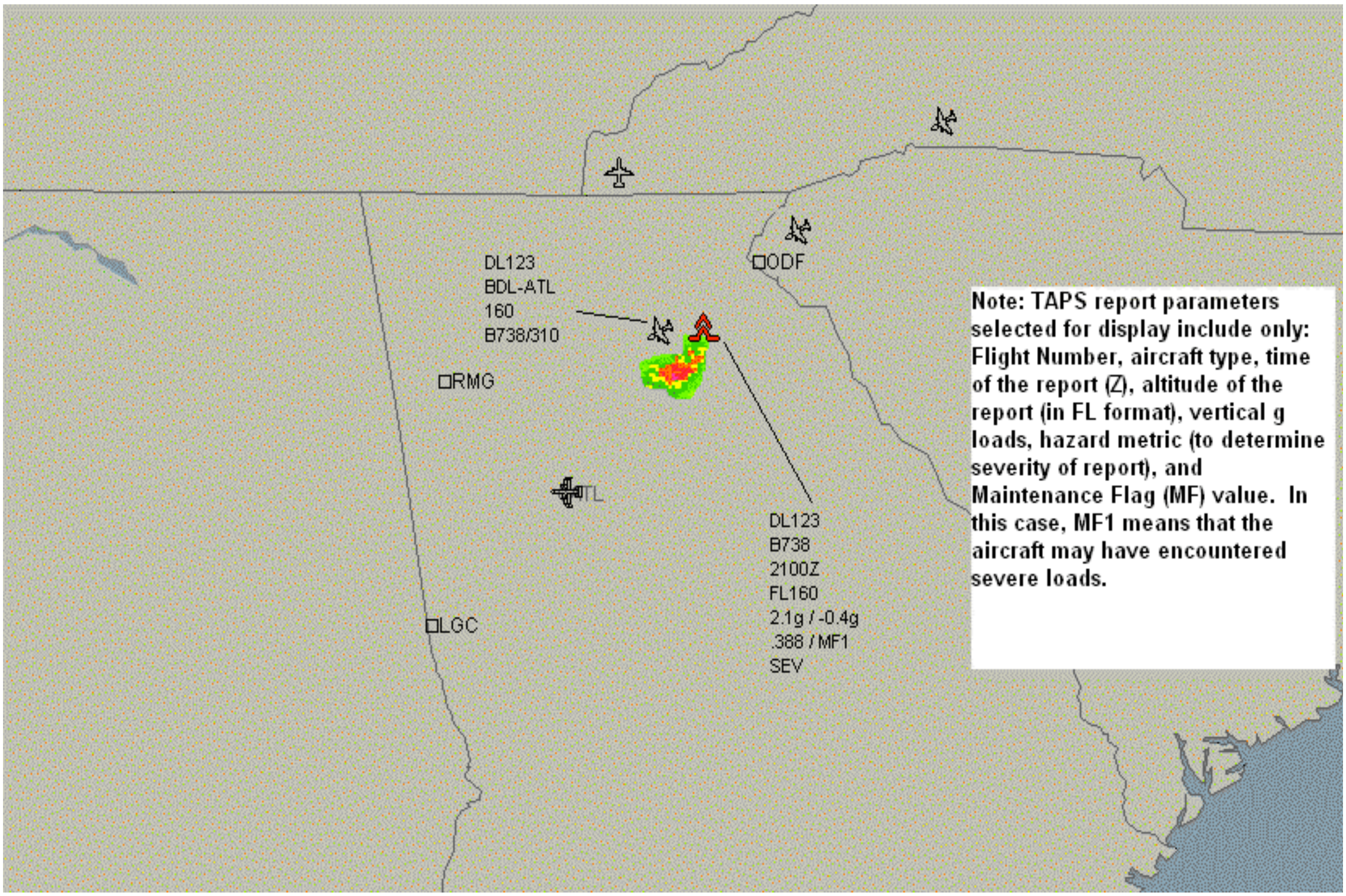


Illustration for Scenario C



Appendix B: E-Turb Radar In-Service Evaluation: Pilot Questionnaire Summary

The following shows all questions and, where applicable, multiple choice responses as presented to the 20 Boeing 737-800 pilots who participated in the questionnaire. Tables and graphs show their responses. Notes summarize responses to each question, including mention of any additional comments that respondents may have made in their answers.

Pilot Questionnaire – Turbulence Procedures, Tools and Techniques

Keeping in mind that all responses will remain anonymous, *please* be as candid yet comprehensive as possible in answering the following.

SECTION 1: General Turbulence Resources and Procedures

1. What tools do you utilize to define areas of turbulence on a flight, how frequently are they referenced, and how do you value the information provided by those tools?

   (For each tool below, respondents had the following choices for their answers)

   Primary Tool: Referenced at least once during any flight
   Secondary Tool: Referenced occasionally or as needed

   Referenced: *Primary* *Secondary* *Rarely* *Never*
   Overall Value: 1 – Occasionally valuable, but usually unreliable or misleading
   2 – Somewhat Valuable most of the time
   3 – Valuable most of the time
   4 – Very Valuable/Essential

<u>Delta Turbulence Forecast</u>

Frequency Referenced

Primary	Secondary	Rarely	Never
5	7	7	1

Overall Value

1 - Least	2 - Somewhat	3 - Most	4 – Essential
7	5	4	4

Alerts from Delta Meteorology

Frequency Referenced

Primary	Secondary	Rarely	Never
0	7	9	4

Overall Value

1 - Least	2 - Somewhat	3 - Most	4 – Essential
2	5	12	1

Flight Plan Weather

Frequency Referenced

Primary	Secondary	Rarely	Never
11	6	3	0

Overall Value

1 – Least	2 – Somewhat	3 – Most	4 - Essential
3	9	7	1

Input from Dispatchers

Frequency Referenced

Primary	Secondary	Rarely	Never
10	9	1	0

Overall Value

1 – Least	2 – Somewhat	3 – Most	4 - Essential
0	4	7	9

ATC Frequency

Frequency Referenced

Primary	Secondary	Rarely	Never
20	0	0	0

Overall Value

1 – Least	2 – Somewhat	3 – Most	4 - Essential
0	1	6	13

Current Generation Radar (Legacy Magenta)

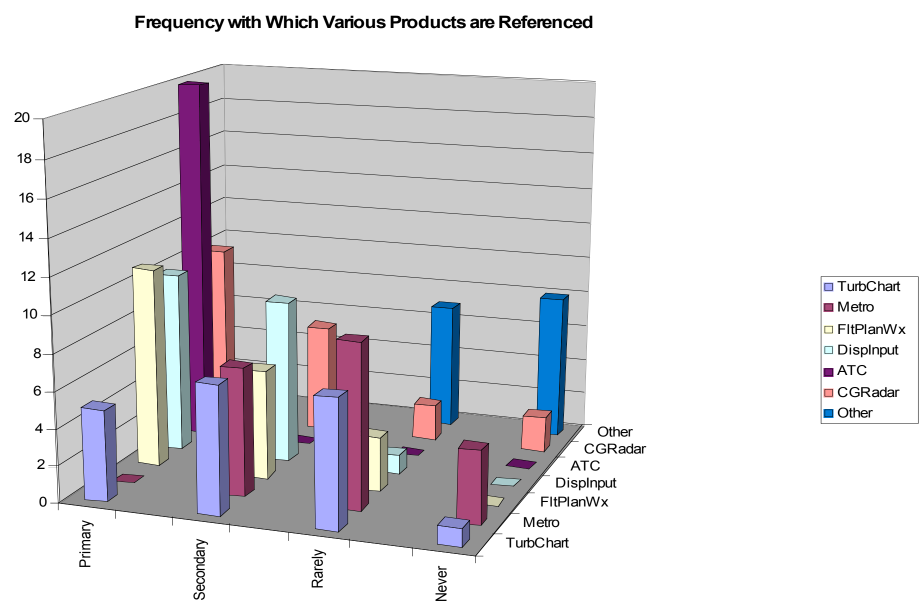
Frequency Referenced

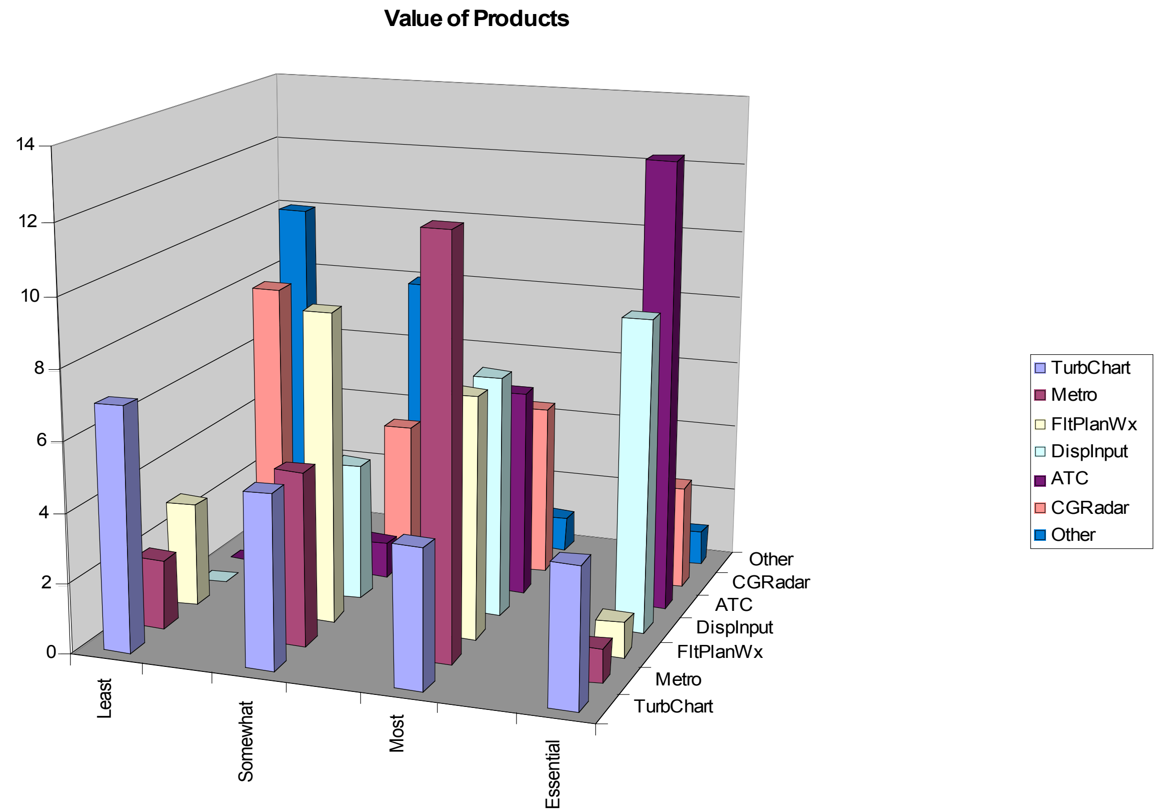
Primary	Secondary	Rarely	Never
10	6	2	2

Overall Value

1 – Least	2 – Somewhat	3 – Most	4 - Essential
8	4	5	3

Notes: Data show pilots generally look at fewer sources for turbulence than dispatchers, potentially because they have less access and training for a lot of sources. As expected, data show the most used and trusted source for pilots are comments regarding ride quality transmitted over the ATC frequency. Flight Plan Weather, a compilation of Forecasts and PIREPS, along with Dispatcher Input are the next most used sources, with reasonable confidence levels. Meanwhile, the most used and generally trusted source for information by dispatchers, the Delta Turbulence Forecast, is seldom used or trusted by pilots. Although Delta Meteorologists are not frequently used to inform turbulence related decisions, the pilots seem to have a reasonable level of confidence in their input. Several comments were made about how subjective and often erratic PIREPS were (e.g. different turbulence levels reported in same area by different crews). In summary, pilots, like dispatchers, have to rely on forecasts which they feel are only correct a little over 50% of the time and real time reports that are not very reliable.





2. During a flight, what minimum level of turbulence prompts you to request a new altitude, deviation, or re-route?

(Respondents had the following choices for their answers)

LGT CHOP LGT TURB MOD CHOP MOD TURB

Pilot Responses	
Light Chop	7
Light Turbulence	8
Moderate Chop	5
Moderate Turbulence	0

<u>Notes</u>: 15 (75%) of the pilots used either Light Chop or Turbulence as a trigger to make a decision about making changes due to turbulence. Several comments were made that indicated pilots would not be as quick to make a change if they had better information.

3. How often (in terms of an overall percentage) do you do the following as a result of your turbulence threshold above:

   (Respondents had the following choices for their answers, filling in percentages as appropriate)

Choice	*Percentage*
Change altitudes with no reroute	66
Reroute with no change in altitude	10
Reroute and a change in altitude	8

4. Do you find a general disparity between the level of turbulence contained in any pilot **reported** information for a given area and the levels of turbulence actually encountered within that area (i.e. Do turbulence PIREPs tend to be conservative in nature, reporting levels of turbulence that are higher than may actually be present, or is it the other way around)?

   (Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Pilot Responses	
Forecasts are too conservative	8
Too Conservative (Request Alt Change)	1
Forecasts vary with forecaster & area	3
Forecasts underestimate turbulence	1
Forecasts are on target	7

   a. If so, how does this affect your practice of turbulence avoidance (Do you account for the disparity in turbulence reports and actual conditions)?

      (Answers to this question were fill-in, and those inputting the data developed the following categories to account for responses)

Pilot Responses	
Account	6
Account – Turn Seat Belt ON	2
Account – Verify Other A/C	2
Account – Avoid all Turbulence	2
Ignore	4

b. Is there a similar disparity between the levels of turbulence that are **forecast** for a given area versus the levels of turbulence actually encountered within that area?

(Answers to this question were fill-in)

Pilot Responses	
Yes	15
No	5

c. More generally, how often (as a percentage) would you estimate that forecasts of turbulence are accurate?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Pilot Responses	*Percent*	*Std Dev*
All Forecasts	53	17
Delta Turb Forecast	65	21

<u>Notes</u>*: Only 7 pilots felt the forecasts were on target, while 8 felt that forecasts over warn, predicting turbulence to be stronger than is actually encountered. Most try to account for this, but they also tend to be very conservative because of their lack of confidence in the information, either avoiding the area or turning on the seat belt sign.*

5. What kind of information do you use in avoiding encounters with ***convective*** turbulence?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Preflight

Information source	
Web Radar	16
Turbulence Chart	5
Flight Plan Weather	11
Inbound Crew	3
Dispatcher	11

<u>Notes</u>*: Nexrad data from the internet and big screen TVs at the gate (where available) are major sources during Preflight, with guidance from the dispatchers on the Flight Plan Weather providing additional information.*

Climbout

Information Source	
Radar	17
PIREPS	14
Reports on ATC Frequency	11
TCAS for location of reporting A/C	1
Visual for location of reporting A/C	4

<u>Notes</u>: Onboard weather radar, ATC, and PIREPS are the primary sources for turbulence avoidance, with dispatchers playing a minimal role.

Enroute

Information Source	
Radar	19
PIREPS	15
Reports on ATC Frequency	12
TCAS for location of reporting A/C	2
Dispatcher	8

<u>Notes</u>: Onboard weather radar, ATC, and PIREPS are the primary sources for turbulence avoidance. Also, the dispatchers appear more active in the Enroute phase by sending more tactical information like PIREPS and updated Convective SIGMETS.

Descent

Information Source	
Radar	18
PIREPS	14
Reports on ATC Frequency	13
TCAS for location of reporting A/C	1

<u>Notes</u>: Onboard weather radar, ATC, and PIREPS are the primary sources for turbulence avoidance, with dispatchers playing a minimal role similar to the climb phase.

a. When operating near thunderstorms in terminal areas, what tools do you use for turbulence avoidance?

Information Source	
Radar	20
PIREPS	11
Reports on ATC Frequency	13
TCAS for location of reporting A/C	3
Wind Information (to determine cell movement)	1

Notes: Onboard weather radar, ATC, and PIREPS are the primary sources for turbulence avoidance. Given ATC constraints, the comments confirmed that fewer options were available in the terminal area, so the crews tend to be very proactive about having the cabin crew and passengers seated and secure. Also, the dispatchers take a less active role in the terminal area.

b. In the terminal area, are PIREPs of convective turbulence valuable to you?

Pilot Responses	
Yes	19
No	1

i. If so, how long do you view these reports to be valid?

Average Minutes	*Std Dev*
14	7

Notes: The duration for the validity was somewhat subjective based on a lack of knowledge concerning how long reports really should be valid.

ii. Would you find real-time, automatically generated, objective reports of convective turbulence more helpful in these areas?

Pilot Responses	
Yes	20
No	0

iii. How long would you view *these* reports to be valid?

Average Minutes	*Std Dev*
16	8

Notes: Here again, the duration was somewhat subjective based on a lack of knowledge as to how long these reports really should be valid.

c. Would you find information concerning the actual turbulence hazard posed by an area of reflectivity (usually in the vicinity of convection) to the aircraft you are flying helpful?

Pilot Responses	
Yes	17
No	2
Null	1

Notes: Most felt this information would be helpful based on their understanding of the radar and assuming that meaningful ways to present the data could be found.

More generally, a common approach to convective weather in all phases of flight was to tightly correlate high levels of radar reflectivity with the level of turbulence that might be expected. This connection seems dubious in many cases based on data and experience with the E-Turb radar. Several comments were made on the importance of human factors in the presentation of the new products, and most pilots felt they would need more training on the integration of the various new products being considered.

6. What kind of information do you use in avoiding encounters with ***clear air*** turbulence?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Preflight

Information source	
Turbulence Chart	10
Flight Plan Weather	16
Inbound Crew	3
PIREPS	6
Dispatcher	5

Notes: The Flight Plan Weather is the major source of information for CAT during Preflight. The dispatchers are also used during this phase. Though viewed to be helpful, the Delta Meteorology Turbulence Forecast/chart is also not readily available to domestic crews.

Climbout

Information Source	
Reports on ATC Frequency	12
PIREPS	19
Dispatch	0
Flight Plan Weather	5
Lenticular Clouds	1

Notes: Reports of turbulence over ATC frequencies and PIREPS are the primary sources for clear air turbulence avoidance. The dispatchers take a less active role in the climb phase.

Enroute

Information Source	
Reports on ATC Frequency	16
PIREPS	19
Dispatch	4
Delta Metro	2
Flight Plan Weather	6

Notes: As in the climb, reports of turbulence over ATC frequencies and PIREPS are the primary sources for turbulence avoidance enroute. Knowing that the workload of pilots is reduced during this phase, dispatchers appear more active, often sending lots of tactical information such as PIREPS and updated AIRMETS/SIGMETS.

Descent

Information Source	
Reports on ATC Frequency	15
PIREPS	19
Dispatch	2
Delta Metro	0
Flight Plan Weather	4

Notes: Here again, reports of turbulence over ATC frequencies and PIREPS are the primary sources for turbulence avoidance. The dispatchers take a less active role in the descent/arrival phase similar to the climb phase.

a. For flights operating near clear air phenomena in terminal areas, what tools do you use for turbulence avoidance?

Information Source	
Reports on ATC Frequency	12
Predictive Wind Shear PWS	1
PIREPS	17
TCAS for location of reporting A/C	2
Airport Terminal Info System ATIS	2

<u>Notes</u>: *Reports of turbulence over the approach frequency and PIREPS serve as the primary sources for turbulence avoidance. As with operations in a convective environment, ATC significantly constrains crew options due to traffic density. Therefore, most pilots ensure that the cabin crew and passengers are seated and secure when operating in the terminal near areas of known CAT. Also, the dispatchers take a less active role in the terminal area.*

b. In the terminal areas, are PIREPs of clear air turbulence valuable to you?

Pilot Responses	
Yes	20
No	0

i. If so, how long do you view these reports to be valid?

Average Minutes	*Std Dev*
21	14

<u>Notes</u>: *The duration for the validity was somewhat subjective based on a lack of knowledge concerning how long reports really should be valid.*

ii. Would you find real-time, automatically generated, objective reports of Clear Air turbulence more helpful in these areas?

Pilot Responses	
Yes	20
No	0

iii. How long would you view *these* reports to be valid?

Average Minutes	*Std Dev*
28	18

<u>Notes</u>: *The duration for the validity was somewhat subjective based on a lack of knowledge concerning how long reports really should be valid.*

c. Would you find electronic turbulence reports scaled to the aircraft you are flying helpful?

Pilot Responses	
Yes	18
No	1
Null	1

Notes: With the understanding that meaningful ways could be found to present the data, nearly all pilots saw value in the TAPS reports.

7. Do you feel that there is phase of flight or an altitude threshold below which you are committed to follow ATC vectors and accept the turbulence as encountered?

   (Answers to this question were fill-in)

Pilot Responses	
Yes	11
No	9

   Notes: The pilots are reluctant to define an altitude below which they are strictly at the whim of ATC, but most admit that their options become fewer as they approach roughly the 10,000 foot mark.

8. When attempting to avoid a given piece of airspace due to turbulence that is either forecast, reported by others, or experienced by you, what steps do you take in coordinating an amended clearance for a re-route, deviation or alternate altitude?

   (Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Steps Taken	
Contact Dispatcher	9
Request approval from ATC	19
Review PIREPS	6
If unsafe, deviate & inform ATC	2
Time permitting, contact Dispatch & Metro	6
In Convective Wx., Radar is primary	3

   Notes: Most confirmed that turbulence reported over ATC frequencies, dispatchers, and PIREPS are the primary information drivers for making their decisions. There is little direct dialogue with the dispatch in the preflight phase. Once airborne, however, the pilot deviates vertically or horizontally based primarily on the PIREPS given on the current ATC frequency, with some input from dispatch if there is time to discuss options. Overall, use of data from only the current ATC frequency results in a very myopic approach and the least chance of attaining the best solution for the flight as a

whole. As noted in the dispatcher results, this begs the question of whether the overall plan is being optimized based on company goals.

9. *Versus requests for alternate altitudes*, how often (in terms of an overall percentage) is it necessary for you to *personally initiate* re-routes (NOT tactical deviations) due to areas of hazardous turbulence?

   (Answers to this question were fill-in)

Average Percentage	Std Dev
6	5

   Notes: *There seemed to be a perception by many in the research community that a lot of reroutes took place to avoid turbulence, but the data appears to show otherwise with respect at least to the activities of both dispatchers and pilots. This excludes tactical deviations for convective activity, and there was some confusion on this question by two of the pilots. After clarification, they changed their percentages as noted on the questionnaire.*

10. How often (in terms of an overall percentage) do areas of turbulence that were *not* forecast (but confirmed by PIREPs or other means like ATC reports on your frequency) result in changes to your altitude and/or route?

   (Answers to this question were fill-in)

Average Percentage	Std Dev
40	25

   Notes: *This question was misunderstood by many of the pilots, and their comments seem to indicate they were being asked in a different way how often the forecast was off in predicting turbulence (Question 4c). Based on the above premise, their responses were generally consistent with Question 4c, with an average of 40% and a standard deviation of 25.*

11. Based on tactical decisions and guidance from ATC in avoiding turbulence on a day to day basis, would you say that the dispatcher's role today tends to be more reactive or proactive when collaborating with flight crews to avoid areas of turbulence during the enroute portion of a flight?

   (Answers to this question were fill-in)

Pilot Responses	
Proactive	5
Reactive	15

Notes: Most who answered "Reactive" qualified their answers by stating that the approach of the dispatcher varies with the phase of flight and the information available to the dispatcher. Many of the comments indicated that pilots rely most heavily on ATC chatter, an approach that does not allow for strategic planning.

SECTION 2: Scenario-based Questions

(Answers to these questions were strictly fill-in, and those inputting the data developed the categories in the tables to account for responses. To make sense of responses to Scenario A, many pilots wrote that they would explore a variety of options, all of which were included in the table.)

Scenario A

12. A Delta B757 flight crew makes a conventional PIREP via ACARS of "moderate chop" during cruise at FL330 over southwestern Utah, and descends to FL270 for a better ride. Due to traffic, the flight is unable to climb again for 30 minutes, devastating fuel consumption vs. what had been planned at FL390. Subsequent to this, the dispatcher reports that recent electronic turbulence reports made in the vicinity confirm the presence of what flight crews would term mostly light, occasional moderate turbulence, but also show the dimensions of the turbulence to be only 80 nautical miles long. Armed with this information, if you were on a flight about to enter this area at FL330, how would you respond operationally to this information?

Pilot Action/Recommendation	
Higher Altitude	4
Lower Altitude	3
Reroute No Altitude Change	0
Reroute With Altitude Change	2
Stay the course with Seat Belt ON	16

Notes: Most pilots indicated that they would stay the course with the seat belt sign ON. Others discussed alternative options based on gathering more information, but even they would consider staying the course if the additional information validated the TAPS data.

Scenario B

13. While settling in for a shift, your dispatcher observes an electronic turbulence report of moderate turbulence lasting 30 seconds or less at FL330 over southern Colorado. Just 3 minutes behind the aircraft that made the report, having been on the exact same route and at exactly same altitude, is another aircraft (of the same type and approximately the same weight) also capable of making electronic turbulence reports. The dispatcher observes, however, that this aircraft made no electronic report of turbulence while transiting the airspace where the first aircraft made a report. If the dispatcher were to give this

information to you as you are about to enter this area, how would you respond operationally to this information?

Pilot Action/Recommendation	
Higher Altitude	1
Lower Altitude	0
Reroute No Altitude Change	0
Reroute With Altitude Change	0
Stay the course with Seat Belt ON	19

Notes: 1 pilot would try for a higher altitude, but noted that otherwise he would stay the course with the seat belt sign ON.

Scenario C

14. Due to convective activity, ATC has cleared you to deviate as necessary for the next 30 miles. Looking at the E-Turb radar display on ship 3708, if you saw solid magenta (denoting an area of moderate turbulence) in an area of low reflectivity (green), and your only other option was to transit an area of yellow, which route would you take?

Pilot Action/Recommendation	
Transit Green with Magenta	3
Transit Yellow with No Magenta	17

Notes: Only 3 pilots would avoid the yellow versus the green, but based on positive comments about E-Turb in other questions on their sheet, it appears they might have confused the question to be asking about the older radar with the inaccurate magenta.

SECTION 3: Historical uses of the E-Turb radar on ship 3708

The following questions relate primarily to any past experiences that you may recall having used the E-Turb Radar on ship 3708. Please answer only in relation to times when E-Turb **magenta** information was presented on the radar display. *If there was never a time when you can recall seeing magenta on the E-Turb display, answer questions 17 and 20-23 only.*

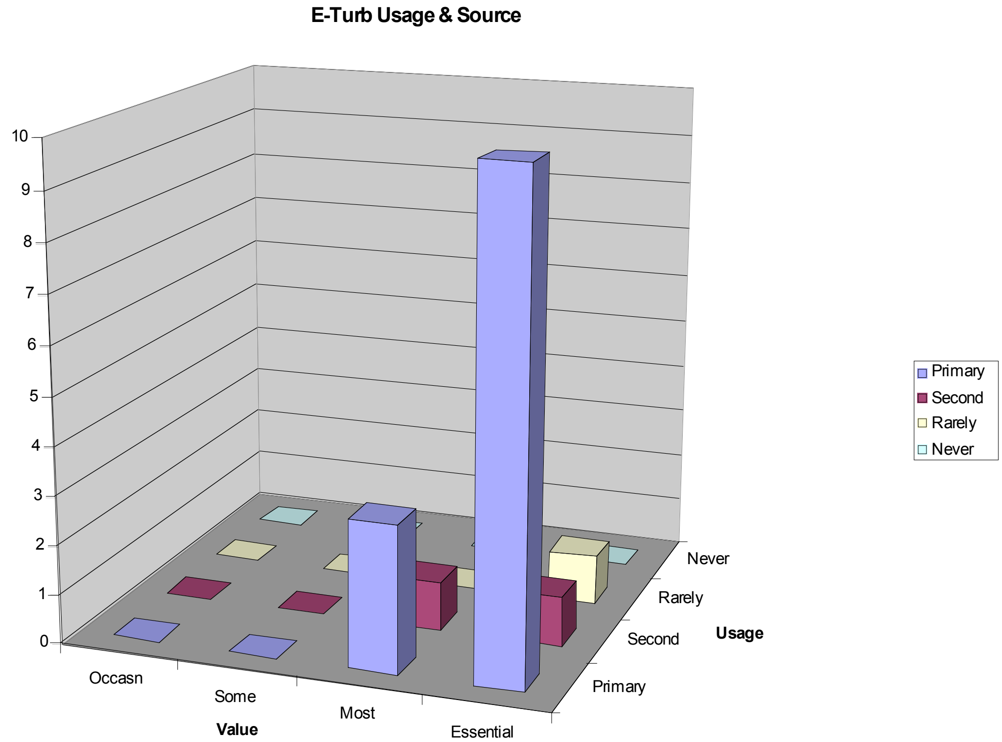
15. How would you categorize your use of the magenta information provided by the E-Turb Radar?

(Respondents had the following choices for their answers)

Referenced:	*Primary* *Secondary* *Rarely/Never*
Overall Value:	1 – Occasionally valuable, but usually unreliable or misleading 2 – Somewhat Valuable most of the time 3 – Valuable most of the time 4 – Very Valuable/Essential

	Primary	Secondary	Rarely	Never
4 – Essential	10	1	1	0
3 – Mostly valuable	3	1	0	0
2 – Somewhat valuable	0	0	0	0
1 – Least valuable	0	0	0	0
NULL	4			

Notes: The pilots were asked to answer only if they had had the opportunity to use the new radar and had actually seen E-Turb magenta on the display, so 4 respondents were Null. Of the remaining 16, a few confused how often they would use the E-Turb if available (which was the intent of the question) vs. how often they had used it (even though exposure was very limited). In any case, all 16 found the information to be either Valuable most of the time or Essential. See Chart 3.



16. Did the information provided by the E-Turb magenta give you confidence in transiting an area of precipitation that you might not have otherwise transited?

(Respondents had the following choices for their answers)

a. Yes/No

Pilot Responses	
Yes	15
No	0
NULL	5

Notes: Of the 5 Null responses, 4 were based on not having used E-Turb as instructed by the questionnaire, and the other Null seemed to be based on limited experience. Importantly, the remaining 15 felt the E-Turb gave them the confidence to transit an area of convective based not on reflectivity but on the actual turbulence hazard.

b. If so, did the magenta information result in a more expedited, efficient routing than would otherwise have been the case?

(Answers to this question were fill-in)

Pilot Responses	
Yes	14
No	0
NULL	6

Notes: *Of the 6 Null responses, 4 were based on not having used E-Turb, and the other two Nulls seemed to be based on uncertainty in evaluating if it were more efficient.*

c. Approximately how many minutes or nautical miles did the routing save?

(Answers to this question were fill-in)

Average Minutes	*Std Dev*
7	7

17. Via the following metrics, please give as many examples as possible of times when real time, E-Turb magenta information either was helpful or could have been helpful in performing your duties?

(Answers to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

a. Turbulence encounters avoided

Pilot Responses	
None	4
Possibly Once	2
Possibly Twice	0
Possibly Several	14

Notes: *Of the 4 "None" responses, several seemed to be based on limited experience. The remaining 16 felt the E-Turb gave them the confidence to transit an area of convective weather based not on reflectivity but actual turbulence. Even so, there was some confusion on what constituted a "turbulence encounter," though it appears many pilots gave the question the benefit of the doubt.*

b. Airframe inspections avoided

Pilot Responses	
None	14
Possibly Once	3
Possibly Twice	2
Possibly Several	1

Notes: Again, there was a lack of comfort with this question since it asked respondents to speculate about a hypothetical. Nevertheless, maintenance inspections are infrequent occurrences, so estimates of savings in this area were minimal.

e. Reductions in traffic flow disruptions

Pilot Responses	
None	8
Possibly Once	2
Possibly Twice	3
Possibly Several	7

Notes: Of the 8 "None" responses, most seemed to have difficulty conceiving how E-Turb information could have impacted traffic flow disruptions.

f. Other benefits (e.g. confidence in flight situation, workload etc.)

Pilot Responses	
Confidence in Forecast	3
Confidence in PIREPS	4
Confidence in new E-Turb Magenta	10
Situational Awareness	10
Reductions in ATC congestion	1

Notes: Most pilots were enthusiastic about other benefits. The most common ones mentioned were confidence in Forecasts, PIREPS, Magenta, and better Situational Awareness.

18. Is E-Turb magenta a valuable tool in Turbulence avoidance?

(Respondents had the following choices for their answers)

Overall Value: 1 – Occasionally valuable, but usually unreliable
2 – Somewhat Valuable most of the time
3 – Valuable most of the time
4 – Very Valuable/Essential

Pilot Responses	
Occasionally Valuable	0
Somewhat Valuable	0
Mostly Valuable	7
Essential	9
NULL	4

19. Did the information provided by the E-Turb magenta give you information concerning turbulence within an area of low radar reflectivity?

    (Responses to this question were fill-in, and those inputting the data developed the following categories to account for responses)

Pilot Responses	
Yes	10
No	6
NULL	4

If so,

a. What constraints (ATC, traffic etc.) did you face while operating near this area, and how did it affect the action you took?

Pilot Responses	
Lack of Situational Awareness	4
No Constraints	6
Too little warning	5
ATC lacks E-Turb info	1

b. Did you transit this area or avoid this area?

Pilot Responses	
Transited	6
Avoided	4
NULL	10

c. If not for the information provided by the E-Turb magenta, what routing would you have taken? (Examples: Transit an area of low reflectivity with potential turbulence without E-Turb knowledge, Avoid a larger block of airspace due to conservative approach for smooth ride)

Pilot Responses	
Longer Route	3
Stay course with Seat Belt	3
Depends on Radar Reflectivity	1
Would have penetrated turbulence based on reflectivity	4
NULL	10

20. New, automatic turbulence reports are capable of being presented in real time as turbulence advisories to the dispatcher and, at some point, to the pilots in the cockpit when turbulence reports are made along the routes of specified flights.

a. Do you feel that these advisories either are or could be helpful?

(Responses to this question were fill-in)

Pilot Responses	
Yes	20
No	0

<u>Notes</u>: *Comments were very supportive of objective TAPS data, although there was concern about the human factor issues concerning presentation, priority schemes, and time stamps on the data.*

21. Would E-Turb from equipped aircraft be helpful or confusing on an Electronic Flight Bag \ for an aircraft not equipped with E-Turb?

(Responses to this question were fill-in, and those inputting the data developed the following categories to account for responses)

Pilot Responses	
Helpful	19
Confusing	1

<u>Notes</u>: *The one pilot who stated that the data would be confusing was not sure how it should be presented. Still, there was widespread concern about the human factors issues concerning presentation, priority schemes, and time stamps on the data.*

22. Do you find the automatic mode on the E-Turb radar (automatic tilt, gain, and ground clutter suppression) helpful?

(Responses to this question were fill-in)

Pilot Responses	
Yes	20
No	0

a. Have there been any times when you took the radar out of automatic mode, and why?

(Responses to this question were fill-in, and those inputting the data developed the following categories to account for responses)

Pilot Responses	
No	5
Yes – Confidence check	14
Yes – Review Vertical Profile	1

23. Do you have any other recommendations to enhance the operational relevance of turbulence information?

(Responses to this question were strictly fill-in, and those inputting the data developed the following categories to account for responses)

Pilot Responses	
Radar ON Warning on Ground	1
Uplink Auto Turbulence reports	4
Better training	4
Install on all A/C	4
Longer range for E-Turb magenta	2
NULL	5

SECTION 5: Personal Background

24. How long have you been a pilot?
25. How long have you been a pilot with Delta?
26. What is your position on the flight deck (Captain or F/O)?
27. Please list your pilot certificates and ratings held.
28. Beyond your pilot certificates and ratings, is there anything else about your background that might be helpful in understanding your responses to this survey (e.g. educational background, military flying, previous encounters with turbulence, previous occupations etc.)?

Demographic Summary	
Average years as a pilot	27
Average years as a Delta pilot	16
F/Os	7
Captains	13
Ratings held: B-737 B757/767 B-777 MD88	 19 9 2 1

SECTION 6: Future uses of the E-Turb Radar on ship 3708

Feedback from flight crews on the continued performance of the E-Turb magenta will be vital, so please tear off this set of questions, and take it along with you for the next time you find yourself aboard ship 3708. The questions below relate to any turbulence you encountered in which the radar either was or could have been helpful. **Responses will be collected solely for the purposes of evaluating this new system, and may be sent via company mail to Christian Amaral, Dept. 026, or e-mail to christian.x.amaral@delta.com.**

1. Were you satisfied with the presentation/design of the 2 levels of magenta (if applicable)?

    a. If not, what did you see as deficient (e.g. definition around the 2 levels, etc.)?

2. Did the aircraft penetrate any area(s) where magenta was indicated?

    a. If so, did you feel that the magenta accurately predicted the level of turbulence experienced (if any)?

3. Was the 25 nautical mile range of the magenta adequate for avoidance and/or the crew's ability to secure the cabin?

4. Did you encounter turbulence within clouds in areas where no magenta was depicted?

    a. If so, would you have liked to have seen that turbulence depicted or was it too light to be worthwhile?

Please feel free to include any other feedback in the space below.

Appendix C

Feedback on TAPS, and Operational Uses of TAPS Data on WebASD by Dispatchers, Meteorologists, and Pilots

Description: Throughout the various phases of deploying TAPS on WebASD among dispatchers, Delta project personnel obtained general feedback concerning TAPS, as well as documentation of times when TAPS data was used within the operation through frequent visits to the Delta Operations Control Center (OCC). The following logs all discussion with dispatchers and meteorologists concerning the system, all known inquiries from pilots regarding TAPS data, as well as all known uses of TAPS between June of 2005 and January of 2006. Because TAPS was not integrated into the applications most referenced by dispatchers, uses of the system usually led to the involvement of project personnel. So although it was impossible to capture *all* uses of TAPS among 135 dispatchers, what follows would seem to approach a comprehensive account. Of particular interest are a few applications of TAPS data in some higher profile encounters with turbulence that resulted in airframe inspections and injuries.

1. Conversation with Dispatcher A

Hasn't had a chance to look at WebASD very much in the last few days, and feels that reports in the vicinity of convection, with the exception of reports indicating severe loads, are not very useful. Pilots and dispatchers know about the thunderstorms when they're around and know to expect a rough ride.

He feels that fall and winter, with fast moving jet streams, will present the best opportunities to leverage TAPS.

Also, when he tried to pull up WebASD, an error message about "low memory" was displayed, presumably because he had a lot of other applications open at the same time.

2. Conversation with Dispatcher B

Hasn't had a chance to look at WebASD very much in the last few days, mainly because he's been very busy and there "hasn't been much turbulence." When there was turbulence, he would have liked to have pulled it up, but was getting behind and therefore didn't access it.

3. Conversation with Dispatcher C

Hasn't been able to spend too much time with the product due to workload, but was able to pull WebASD up and knew his way around the application. He also mentioned that another dispatcher had helped show him a few features last week. Otherwise, he's happy with the system and the display.

4. Conversation with Dispatcher D

Likes the product in general and is thrilled with the basic idea of TAPS, but would prefer to see a way for WebASD to be more integrated into how dispatchers go about their duties.

- For example, having to enter all of the flight numbers that a dispatcher may be handling is cumbersome and will seriously inhibit the use of TAPS for targeted Advisories and Scaling. It would be great if this could be automated and imported into WebASD in some fashion, based perhaps on the user's profile login name interfacing with his unique duty roster for that day.
- Also, there is no ability for dispatchers to cut and paste anything from a TAPS report on WebASD into an ACARS message that could quickly and easily be sent to pilots for a notification of turbulence represented by a TAPS report. Additionally, even if one *were* able to do this, that information needs to be conveyed in a manner more easily assimilated than lat/long and a number like rms g. References to VORs and navaids would be ideal.

Feels that integration into GFF would greatly enhance the face time that people have with TAPS, since even in a high workload environment, GFF is up as a primary desktop application. This is not remotely the case with WebASD.

Even so, he'd like to see TAPS on WebASD deployed sooner rather than later and feels it is certainly a worthwhile addition to the floor.

5. Conversation with Dispatcher E (working Delta Shuttle desk)

Had WebASD available (minimized) on the desktop, though he admitted he hasn't looked at it very much in the last couple of days due to a high workload. He then asked how to display certain aircraft, and how to scale reports. When showed how to perform these tasks, he remarked, "that looked easy enough," and otherwise looks forward to getting the tool deployed more widely.

6. Conversation with Dispatcher F (8/22/05)

During a recurrent training session, dispatcher remarked that turbulence associated with convection is obvious, and TAPS reports in the vicinity of thunderstorms were therefore not very useful. Pilots reference the onboard weather radar and tend to be conservative in avoiding these areas and/or ensuring the security of the cabin.

7. Conversation with Dispatcher G (8/22/05)

It would be great if information from reports on WebASD could be cut and pasted into an ACARS message that could then be sent in an easily understandable format to crews.

Useful information for such an interactive feature would include: (1) turbulence severity (2) airframe type (3) altitude of the report (4) time of the report and (5) lat/long of the report.

Additionally, perhaps reports of moderate or greater turbulence could be extracted, translated and sent to dispatchers' message queues. This would ensure immediate notification of significant turbulence events for those whose WebASD displays might be minimized.

8. Conversation with Dispatcher H (8/25/05)

During a tour of the OCC with program partners from NASA and Rockwell Collins, Dispatcher H had WebASD available on one of his three workstation monitors. When asked by a tour participant about what he thought of TAPS so far, he stated that it was a "great tool" that has helped him to confirm or deny the presence of turbulence in various areas and along certain routes. This has aided in hazard avoidance/preparedness, and is beginning to pay off in planning flights more efficiently based on the better information that TAPS is providing.

As an aside, given the audience, I wonder if the dispatcher was more concerned with helping to echo a positive message about TAPS and its potential. It would be interesting to know of specific instances in which he used TAPS to do what he said he's been doing.

9. Conversation with Dispatcher I (8/30/05)

As a follow-up to a conventional PIREP of severe turbulence on a 737-800 from the previous evening, dispatcher mentioned that, though he did not have TAPS on WebASD open at his workstation at the time that the PIREP was made (about 1 hour after the encounter), the OCC sector manager sent him a snapshot of the display which clearly showed the associated TAPS reports (both moderate – no mx flag). Knowing how to read the information, he felt TAPS would have been very useful in helping him to say to the captain, "I don't disagree with your assessment, but here's what happened to your airplane," thereby dissuading the call of "severe," and saving the delay of 1 hour and 27 minutes that was required for a maintenance inspection. Moreover, after receipt of the conventional PIREP, dispatcher told a crew flying nearby about it. But by the time this was communicated, the aircraft was already in the potential "danger zone," and the turbulence had dissipated anyways. Had the crew been there 10-20 minutes earlier, though, TAPS would have been a crucial real-time advisory tool.

Though he's had WebASD open on previous occasions, he has not used it much due to screen real estate issues. This experience encouraged him to use WebASD as at least a first reference in future instances. He also remarked that he was very impressed with TAPS and saw the system's operational relevance very clearly.

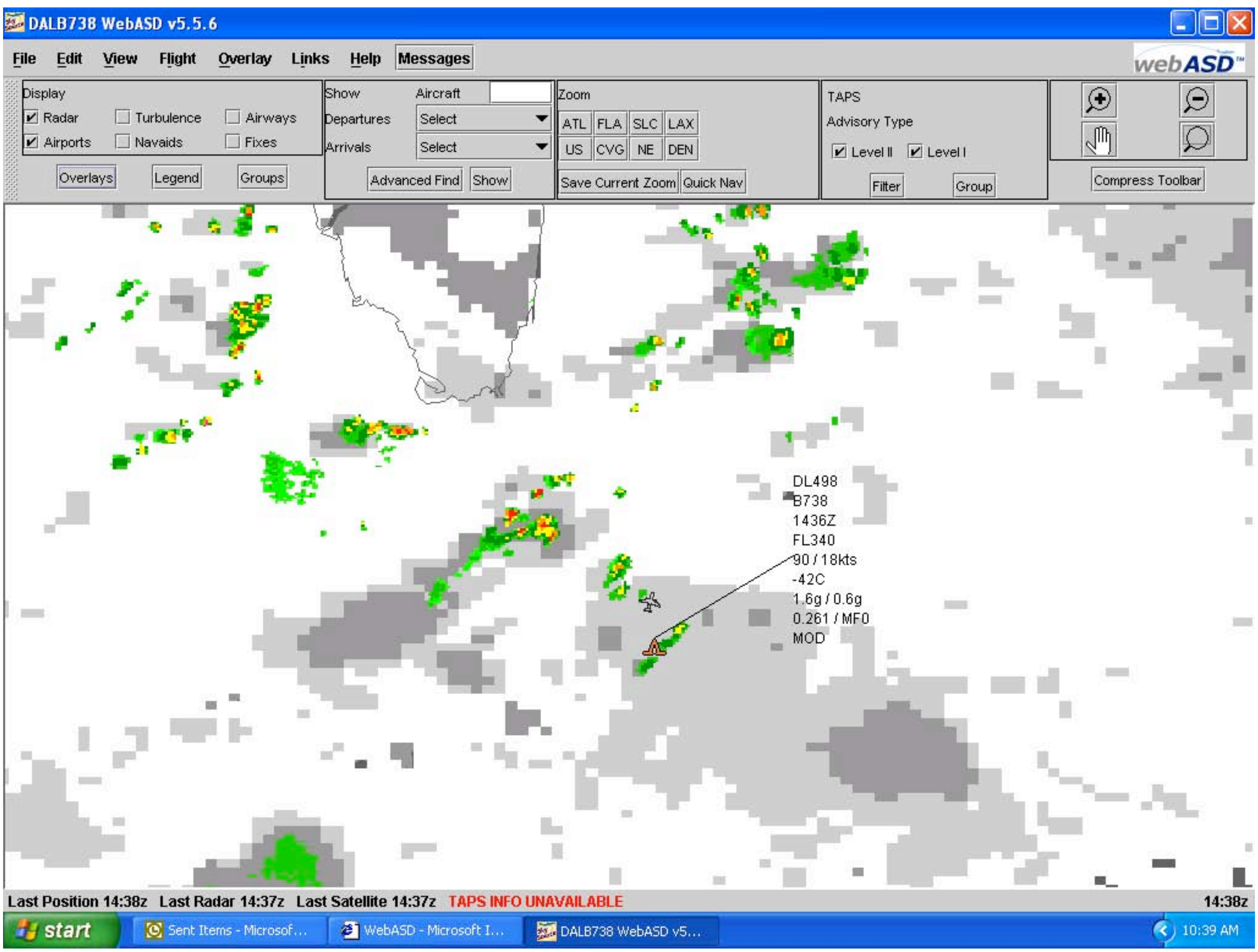
TIMELINE: The TAPS reports occurred at 2151Z, and the captain estimated his encounter with severe as having occurred at 2220Z, in the same location as the TAPS reports. The

conventional PIREP was made after landing at 2245Z, and the advisory to the other aircraft near where the encounter occurred happened at 2306Z.

10. Conversation with Dispatcher J (9/2/05)

After seeing a TAPS report of moderate turbulence from flight 498 (PTY-ATL) north of Cuba, feedback from dispatcher handling the flight was solicited. Dispatcher did not have WebASD available at his workstation, but quickly pulled it up. Though the crew had not sent any message regarding the encounter, Fred was impressed to see the report and stated that he'd be sure to monitor the display for the rest of the shift and, in general, more often on future shifts. He also stated that he'd send a message about the report to Flight 912 (a 737-800 from CCS-ATL), which would soon past east of where the report was made.

Report Snapshot:



11. Email from Meteorologist A (9/2/05)

Email from Meteorologist:

Today is a day TAPs does not adequately portray what is going on. Only 2 flights reported light turbc over the Ohio Valley-Midwest on TAPs. But there is a ton of reports of moderate turbulence. DL1176 rptd mdt turbc btwn CVG-MCI at FL360 and we didn't see anything on TAPS. If you check out the ADDs PIREP page, you can see all the activity.

Reply:

Meteorologist,

Thanks for the feedback. Having been on flights where we experienced what the pilots called moderate turbulence even though no TAPS reports were made, I'd agree that the threshold for a TAPS report to be issued is fairly high. We know it's giving us good, scientifically valid information, but because the software was coded so as not to clutter WebASD too much, there are some cases in which we're not seeing all turbulence that crews are perceiving as operationally important. That, I think, may change with future installations, and this kind of feedback definitely helps make the case to do so.

Still, apart from the 3 flights you mentioned, I wonder what the coverage of TAPS equipped aircraft was in this area. Also, how long are you displaying TAPS reports on WebASD? You can show reports as old as 12 hours, but maybe some fairly recent reports were not there b/c you're seeing reports that are only an hour old.

Regardless, I think it's safe to say that even the lower end of "light" turbulence on TAPS equates to what many crews would deem "moderate." Thanks again for the feedback and keep it coming!

12. Conversation with Dispatcher K (9/7/05)

After seeing 2 TAPS reports of severe turbulence from flight 149 (FCO-JFK) west of Rome over the Mediterranean Sea, feedback from dispatcher handling the flight was solicited. Dispatcher did not have WebASD displayed or minimized, and stated that he had accessed the tool in the past but didn't know what to do with it once it was open. I walked him through the information available in a report, and showed him how to use the zoom functions as well as generally navigate the display to show areas of interest.

He was impressed to see the severe reports from flight 149, and remarked that flight 77 (FCO-ATL, schedules to depart after flight 149) had been held on the ground for over an hour due to thunderstorms in the vicinity. The following ACARS dialogue ensued.

07SEP1450RK 9EE238
CMD

AN N182DN/GL AOE2

1. QUATLDDDL.1DISPATCHER

** PLEASE ACK **
NOTICED SOME CONVECTIVE ACTIVITY ON CLMB OUT..DID YOU EXPERIENCE ANY SIGNIFICANT TURB ON CLMB OUT..ESP AROUND FL150-160
RICK KNELL/34

.QXSXMXS 071534
A80
FI DL0149/AN NXXXDN
DT QXT AOE2 071534 M63A

1. 3401/07 LIRF/KJFK .NXXXDN

YES WE HAD MODERATE + TURBULENCE IMC IN COVECTIVE AREA W TSTRMS LIGHTNING. AIRSPEED AND ALT FLUX +- 15 KTS. AND +-500 FT IN VCNTY OF STORM.

13. Conversation with Dispatcher L (9/7/05)

While in the OCC, dispatcher asked for input on the following scenario. After receiving a conventional PIREP of moderate turbulence from flight 352 (a B737-800) at FL370 over RZC (a VOR located in northwestern Arkansas), he was puzzled at the lack of any corresponding TAPS report(s) on WebASD. He then queried the crew of flight 1409 (an eastbound B737-800) about turbulence in the same area at FL360. The following ACARS dialogue ensued:

07SEP1356JC 079933

1. QUATLDDDL.1DISPATCHER

** PLEASE ACK **
GOOD MORNING

PIREP PLS. THX
FLIGHT CONTROL

.QXSXMXS 071358
A80
FI DL1409/AN NXXXDZ

1. 3401/07 KATL/KSLC .NXXXDZ

SAT -47 CLR MOSTLY SMOOTH 316/037

07SEP1359JC 079933

1. QUATLDDDL.1DISPATCHER

** NO ACK REQ **
ACK. THX....JUST GOT RPT OF MDT AT RZC AT FL370.

A80

FI DL1409/AN NXXXDZ
DT QXS OKC1 071401 M14A
1. 3401/07 KATL/KSLC .N176DZ
WE HEAR ALOT OF PEOPLE STATING MOD BUT WEVE BEEN GOOD KNOCK ON WOOD

07SEP1402JC 079A39
- QUATLDDDL.1DISPATCHER
** NO ACK REQ **
I THINK WE HAVE SOME REAR-ENDS THAT NEED TO BE RECALIBRATED.....I DONT BELIEVE ITS ANY MORE THAN OCNL MDT....AND RARE AT THAT

QU ATLDDDL
A80
FI DL1409/AN NXXXDZ
DT QXS TUL1 071402 M15A
1. 3C03 1409/07 KATL/KSLC
/POS IRW /OVR 1404/NXT JNC /ETA 1522
/ENS KSLC /ALT 360/FOB 0290/SAT 47
/WND 310030/MCH 80/TRB SMOOTH /SKY SCATTERED/ICE NONE

.QXSXMXS 071404
A80
FI DL1409/AN NXXXDZ
DT QXS MCI1 071404 M16A
1. 3401/07 KATL/KSLC .N176DZ
LOTS OF COFFEE DRINKERS THIS TIME OF THE DAY

Dispatcher did see some wind shear based on MDCRS data in the area from FL350-FL390 to substantiate these claims (along with a TAPS report in southwestern Missouri of .090 rms g), but also remarked that true moderate turbulence tends to be vastly underestimated by pilots. I remarked that I wasn't surprised by the lack of TAPS data, having been on flights when the ride was uncomfortable but did not trigger any TAPS reports. He seemed comfortable with this conservative approach to the initial coding of TAPS, but also remarked that turbulence that is even *perceived* as moderate should be captured by future installations since it is seen to be of operational significance even if it's not truly moderate.

14. Conversation with Dispatchers M and N, 10/5/05

Following up on an event the previous week over southern UT, dispatcher M provided information on the amount of fuel required for a flight plan step-down due to a report of turbulence.

He felt that using TAPS reports to generate operational efficiencies was realistic, though there are process constraints that would need to be overcome. Usually, flight planning below FL300 happens in the winter, when strong jet streams across the CONUS wreak

havoc enroute. Particularly in high traffic sectors along the east coast, the scrambling that occurs when flight crews start looking for a smooth ride results in ATC restricting traffic above a certain flight level. RVSM has offered more flexibility, but dispatcher N remarked that ATC still gets overwhelmed by tactical requests for altitude changes, and eventually shuts down airspace above a certain Flight Level, sending airplanes "along the interstate."

TAPS Being Used by a Dispatcher

01JUN2138BG 079928
CMD
AN N3736C/GL TPA
1. QUATLDDDL.1DISPATCHER
** PLEASE ACK **
FYI DL1248 JUST REPORTED MDT AT FL360 OVER SZW

ATL FLIGHT CONTROL....93

QU ATLDDDL
.DDLXCXA 012143
A80
FI DL1286/AN N3736C
DT DDL TPA 012143 M30A
1. 3401/01 KTPA/KSLC .N3736C
THANKS FOR THE HEADS UP

01JUN2146BG 079928
CMD
AN N3736C/GL TPA
1. QUATLDDDL.1DISPATCHER
** NO ACK REQ **
THE REPORT CAME FROM THE 737 (800) THE PILOT NEVER SAID ANYTHING. I AM USING THE NEW NASA TURBC PROGRAM..

ATL FLIGHT CONTROL....93

The Role of TAPS in NTSB Injury Accident, DL612, BDA-BOS, 10/22/05

-----Original Message-----
From: Delta Flight Safety
Sent: Monday, October 24, 2005 9:27 AM
To: Delta Turbulence Project personnel
Subject: B737-800, Ship 3706, Flight 612, BDA-BOS, Moderate Turbulence Encounter

We had an event over the weekend that involved an encounter with moderate turbulence and a FA injury. Do you have a recording of this event (B737-800, xxxxx, Moderate Turbulence Encounter)? Any information you could provide would be extremely helpful.

Thanks

-----Original Message-----
From: Delta Turbulence Project personnel
Sent: Monday, October 24, 2005 10:26 AM
To: Delta Flight Safety
Subject: RE: B737-800 BDA-Bos, Moderate Turbulence Encounter

An initial look at the data indicates that there were indeed TAPS reports associated with this event, one of which was severe by TAPS standards (the airframe was still not compromised, though). I've included the flight history which includes the ACARS message traffic along with the TAPS reports (denoted by a "TRP" in the freetext portion of the message). Within those reports, rms g loads are highlighted in red (explanation: basically, any rms g value below .1 is deemed light turbulence, anything between .1 and .2 is light-moderate, anything between .2 and .3 is moderate, and anything .3 or greater is severe). Peak g loads (both above and below 1 g) are also highlighted in magenta.

Sorry this is so cryptic – because the event happened over 12 hours ago, we don't have a picture of the report like I showed you on the WebASD display. Instead, we have to rely on the data available in flight history.

Please feel free to call with any questions or to discuss more. I'd like to learn more about the encounter myself.

Thanks

Flight History Capture:

A80
FI DL0612/AN NXXXDA
DT QXS PVD1 221815 M41A
1. 3C03 0612/22 TXKF/KBOS
/POS ADYNA /OVR 1805/NXT KBOS /ETA 1852
/ENS /ALT 340/FOB 0140/SAT 49
/WND 238098/MCH 75/TRB LT CHOP /SKY CIRRUS /ICE NONE

.QXSXMXS 221821
DFD
FI DL0612/AN N376DA
DT QXS PVD1 221821 D17A
- TRP 180015 38.2070 -67.8358 340 143.8 793 0.425 0.02009
94.5 -110.04 1.767 -0.248 0.110 -0.077 -49 00 00 00 285 1

.QXSXMXS 221821
DFD
FI DL0612/AN N376DA
DT QXS PVD1 221821 D18A
- TRP 181745 40.1749 -68.9097 339 142.0 752 0.100 0.02035
95.5 -115.66 1.220 0.808 0.040 -0.046 -49 00 00 00 263 0

.QXSXMXS 221822
DFD
FI DL0612/AN N376DA
DT QXS PVD1 221822 D19A
- TRP 181945 40.4022 -69.0292 335 141.8 736 0.087 0.02068
81.5 -113.91 1.217 0.835 0.046 -0.043 -49 00 00 00 261 0

.QXSXMXS 221823
A80
FI DL0612/AN N376DA
DT QXS PVD1 221823 M43A

1. 3401/22 TXKF/KBOS .N376DA

ENCOUNTERED BRIEF MOD TURB ENROUTE. F/A INJURED. DOCTOR LOOKED AT HER. SAID SHE WAS OK. WOULD LIKE PARAMEDICS

22OCT1825KC 079D10
CMD
AN N376DA/GL PVD1

1. QUATLDDDL.1DISPATCHER

** PLEASE ACK **
CPY WILL NOTIFY BOS AND INFLT OF SITUATION

QU XXXXXDL ATLFMDL
.ATLXGDL 221833
CC 14:24:02 10 BOS
DL612 RQ PATCH W/CO DD38
ATL R SB DL612/DD MOD TURBLC INJURED F/A...F/A IS PREGNANT AND HER LEG IS NOW INJURED...DR ON BOARD SAYS SHE WILL BE OKAY BUT WUD LIKE PARAMEDICSTO MEET THE FLT...DR SAYS HER BABY SEEMS FINE BUT SHE IS UNABLE TO STAND AT THIS TIME...DR SAYS F/A LEG IS NOT BROKEN BUT HAS BECOME MORE PAINFUL IN LAST FEW MINUTES....ALSO 2 PAX ONBOARD THAT ALSO REQUEST PARAMEDS...ONE PAX HAS HAD BACK INJURIES IN PAST AND NOW SAYS IS HAVING SOME PAIN...A FEMALE PAX INDICATES HER KNEE IS IN PAIN...F/A HUSBAND
DD CPY...WILL PASS INFO ON...CLR 1833

-----Original Message-----
From: Delta Flight Safety
Sent: Monday, October 24, 2005 10:31 AM
To: Delta Turbulence Project personnel
Subject: RE: B737-800, BDA-Bos, Moderate Turbulence Encounter

Wow, so looks like the .425 would be severe. I would expect severe with the 1.725 and -0.248. Do you agree, or have any other thoughts?

From: Delta Turbulence Project personnel
Sent: Monday, October 24, 2005 10:36 AM
To: Delta Flight Safety

Cc:
Subject: RE: B737-800 BDA-Bos, Moderate Turbulence Encounter

That's correct – b/c the flaps were at 0 degrees, though, the airframe limitations are 2.5 g and -1 g, so in this case neither limitation was exceeded for inspection purposes. This captain is a John Wayne, though, when it comes to determining what is severe and just moderate by a pure seat of the pants metric.

Do you know if the encounter happened in cloud?

Follow-up from Flight Safety:

Yes the incident did happen in a cloud layer. The Captain reported that no returns were painted on the radar screen in the immediate vicinity.

From: Delta Flight Safety
Sent: Wednesday, October 26, 2005 5:13 PM
To: Sr VP, Flight Ops and Chief Pilot
Cc: Sr VP, Corp Safety Security and Compliance; Director, Flight Operations; Director, Flight Safety; Director, Fleets
Subject: 737-800, BDA-BOS, Flight Attendant Injury

Captain X,
(Note: This information is provided per your request to Director, Flight Safety.)

BDA-BOS, Flight Attendant Injury

While in cruise at FL340, the aircraft encountered severe turbulence. (Note: the Captain reported the turbulence as moderate. TAPS defined the turbulence as severe.) The seat belt sign was illuminated at the time of the event. A flight attendant, who was in the aft galley at the time of the event, sustained a fractured pelvic bone The NTSB classified the event as an injury accident.

The weather at the time of the accident was as follows:
- The Captain reported the flight had just entered a high cirrus layer of clouds.
- The radar was on and no returns were noted at the aircraft's altitude.

The Flight Operations and Maintenance Remarks section on the flight release noted the following:
- "TRBC…COMPUTER ANALYSIS USED FOR BEST/NEXT BEST ROUTE…PSBL LGT CHOP TODAY HOWEVER MOSTLY SMOOTH"
- "TRWS – ISOLD TO WDLY SCTD CELLS PSBL OVER THE WATER TODAY"

There were no PIREPS for the route of flight. (Note: The flight was out of range of radio communication with NY center and could not receive enroute pilot reports. The crew had flown the previous leg BOS – BDA and had experienced only light turbulence over the route of flight.)

-----Original Message-----
From: Delta Flight Safety
Sent: Wednesday, October 26, 2005 5:21 PM

To: Delta Turbulence Project personnel
Subject: FW: 737-800, BDA-BOS, Flight Attendant Injury

Can you define this in detail for my response?

From: Sr VP, Corporate Safety
Sent: Wednesday, October 26, 2005 5:18 PM
To: Flight Safety
Subject: RE: 737-800, Flight Attendant Injury

Flight Safety:

A few questions:

- Was this aircraft TAPS equipped.
- Any TAPS reports for that altitude
- Was the general area TAPS plotted

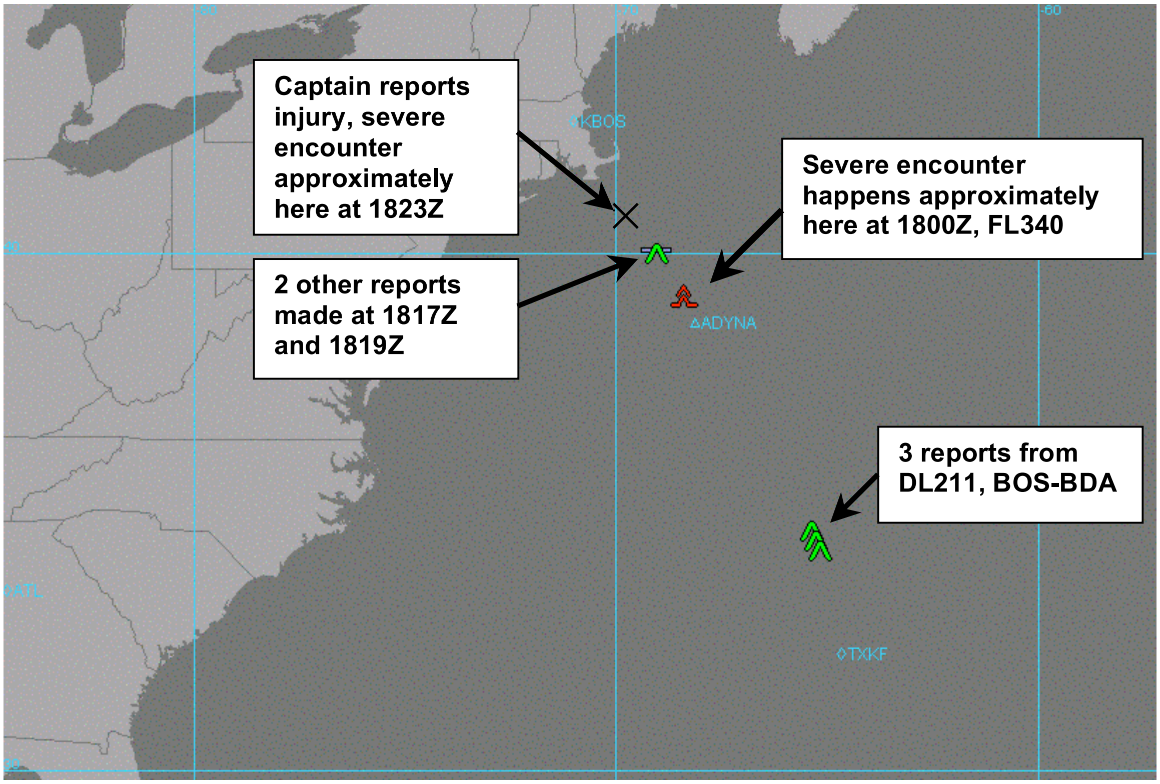
Sr VP, Corporate Safety

From: Delta Turbulence project personnel
Sent: Thursday, October 27, 2005 12:01 PM
To: Delta Flight Safety
Subject: RE: 737-800, BDA-BOS, Flight Attendant Injury

As a 737-800, the aircraft was TAPS equipped. Because I found out about the incident more than 12 hours after it occurred, I couldn't access the display that would have shown whether there were any reports from *other* aircraft in the vicinity of the encounter. However, TAPS equipped traffic in the area where the event occurred would have been pretty sparse. The 767Ers coming from Europe would have been our best bet for TAPS data in this area, but they most likely would have been coming off the North Atlantic Tracks further to the north on their way to JFK or inland towards ATL. So basically, my guess is that there would have been no warning provided by other TAPS reports in the area.

However, we do know what the incident aircraft reported, and basically it's as appears in the re-construction attached (see below). The severe encounter happened at FL340. Notice, however, the discrepancy between the time that the event occurred and the time that it was reported by the captain via ACARS. Had a dispatcher been looking at this, and had the event happened on a busier route, he or she would have had a real-time notification of the event to warn other aircraft in the vicinity.

Let me know if you need any more info.



Delta Flight Safety then requested a decode "key" for the ACARS-based TAPS reports, to be provided to the NTSB in its investigation. TAPS data was to be used essentially as a substitute for DFDR data, since the NTSB lab in Washington DC would have been unable to look at the recorder for weeks. Providing this data would have allowed the recorder to be released back to Delta, where it would have been examined by Flight Safety and shared with the NTSB.

From: Delta Turbulence Project personnel
Sent: Friday, November 18, 2005 11:34 AM
To: Delta Flight Safety
Subject: TAPS decode/NTSB issue

Following up on the flight 612 accident, did the TAPS data/decode satisfy the NTSB so that the DFDR could be released back to Delta and then shared?

It was a huge help in assisting in the release of the DFDR. Thanks a million for your help. I know I was a pest. Have I shared a copy of the DFDR with you?

TAPS Information Being Requested by Pilots, DL323, CVG-PDX, 11/1/05

.QXSXMXS 020506
DFD
FI DL0323/AN NXXXXC
DT QXS IDA1 020506 D86A
- TRP 050535 42.5308 -108.6953 360 139.0 753 0.162 0.01985

57.5 -88.59 1.614 0.661 0.054 -0.097 -56 00 00 00 257 0

.QXSXMXS 020507
DFD
FI DL0323/AN NXXXXC
DT QXS IDA1 020507 D87A
- TRP 050605 42.5480 -108.7702 360 139.0 733 0.309 0.02009
  44.5 -82.97 1.820 0.604 0.100 -0.089 -53 00 00 00 249 0

.QXSXMXS 020507
DFD
FI DL0323/AN NXXXXC
DT QXS IDA1 020507 D88A
- TRP 050635 42.5652 -108.8368 360 139.0 751 0.325 0.02036
  41.0 -75.59 1.696 0.524 0.088 -0.180 -53 00 00 00 250 0

.QXSXMXS 020508
DFD
FI DL0323/AN NXXXXC
DT QXS IDA1 020508 D89A
- TRP 050705 42.5823 -108.9095 360 138.9 729 0.206 0.02035
  36.0 -78.05 1.632 0.295 0.139 -0.161 -52 00 00 00 239 0

.QXSXMXS 020509
DFD
FI DL0323/AN NXXXXC
DT QXS IDA1 020509 D90A
- TRP 050735 42.5988 -108.9782 358 138.8 685 0.208 0.02095
  27.5 -91.05 1.641 0.540 0.165 -0.144 -50 00 00 00 230 0

.QXSXMXS 020511
DFD
FI DL0323/AN NXXXXC
DT QXS IDA1 020511 D92A
- TRP 050805 42.6160 -109.0434 360 138.8 754 0.218 0.02133
  50.5 -89.65 1.405 0.393 0.159 -0.112 -50 00 00 00 250 0

.QXSXMXS 020516
A80
FI DL0323/AN NXXXXC
DT QXS IDA1 020516 M71A
1. 3401/01 KCVG/KPDX .N3742C

MODERATE PLUS TURB OVER KCPR FL320 THRU 380...LASTED APROX 4 MINS

.QXSXMXS 020626
A80

FI DL0323/AN NXXXXC
DT QXS PSC1 020626 M73A
1. 3401/01 KCVG/KPDX .N3742C
DID U RECVE A TAPS RPT FROM OUR TURB OVR KCPR..

02NOV0630DE 9EE119
CMD
AN N3742C/GL PSC1
1. QUATLDDDL.1DISPATCHER
** PLEASE ACK **
YES I RECEIVED IT AND FORWARDED IT TO THE OTHER DISPATCHERS HAVING FLTS IN THE AREA AND ALSO TO METRO. MY ONLY QUESTION IS THE LINE OF FLIGHT I HAVE FOR YOU SHOWS YOU 60-100NM SOUTH OF KCPR. I GUESS THAT IS JUST THE SOFTWARE ESTIMATING YOUR POSN?

.QXSXMXS 020634
A80
FI DL0323/AN NXXXXC
DT QXS PSC1 020634 M76A
1. 3401/01 KCVG/KPDX .N3742C
YES. WE WERE SOUTH OF KCPR..DO U KNOW WHAT THE G LOADS WERE..

02NOV0637DE 9EE23B
CMD
AN NXXXXC/GL PSC1
1. QUATLDDDL.1DISPATCHER
** NO ACK REQ **
WE ARE HAVING INTERNET PROBLEMS AND I CANNOT GET TO THE PAGE THAT HAS THAT INFO ON IT. WILL CONTINUE TO TRY.

It was later discovered that the Delta network was experiencing problems accessing the internet this night, and the dispatcher advised that she otherwise references WebASD infrequently.

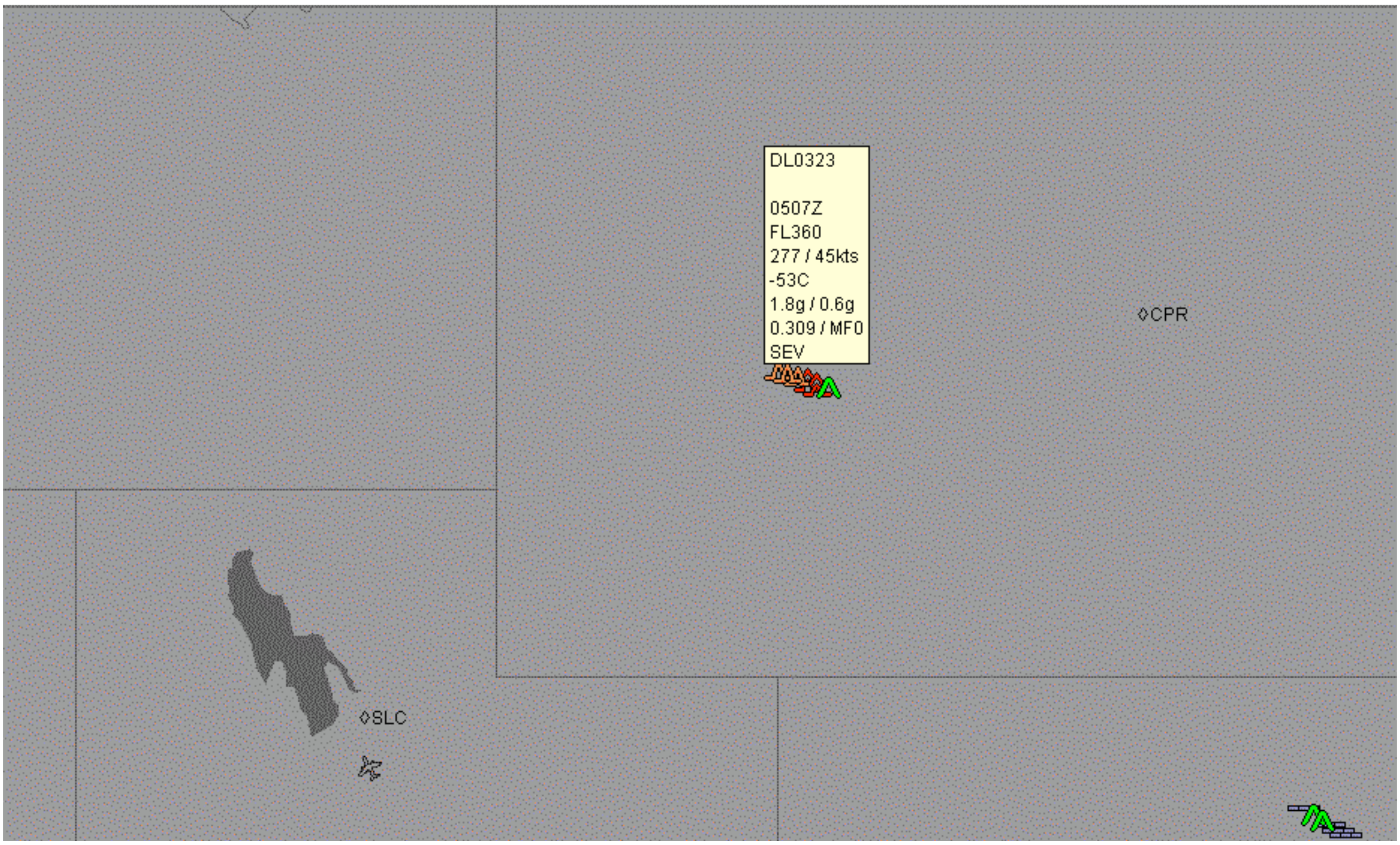
The pilot then queried another dispatcher while flying another leg the following day.

.QXSXMXS 022018
A80
FI DL0890/AN NXXXXY
DT QXS BIS1 022018 M67A
1. 3401/02 KPDX/KCVG .NXXXXY
CAN YOU ACCESS THE TAPS REPORT FROM OUR FLT 323 FROM 11/1 NEAR KCPR. CURIOUS TO KNOW THE REPORTED TURB LEVEL. THX

02NOV2020RC 9EE11A
CMD

AN NXXXXY/GL BIS1
1. QUATLDDDL.1DISPATCHER
** NO ACK REQ **
WILL SEE WHAT I CAN DO

The dispatcher then visited the office of the project pilot, who explained what TAPS had reported with a WebASD snapshot of the encounters (below). The dispatcher who relieved him then sent the following message.



02NOV2140BM 9EE310
CMD
AN NXXXXY/GL CID1
1. QUATLDDDL.1DISPATCHER
** PLEASE ACK **
THE TAPS REPORT GENERATED FROM FLT 323/01 AT 0507Z DETERMINED THE TURB LEVEL IN THE LOW END OF THE SEVERE RANGE. THE TURB WAS WITHIN LIMITS OF AIRFRAME.

Bill Watts then spoke with the captain over the phone, elaborating on the g loads that were encountered and on TAPS in general. The captain appreciated the follow-up.

TAPS Information Being Requested by Pilots, 11/4/05

At the urging of project personnel, this technical pilot inquired about TAPS during a trip.

.QXSXMXS 041649
A80
FI DL0683/AN N176DZ
DT QXS MCO1 041649 M17A

1. 3401/04 KATL/MKJS .N176DZ

NO PIREPS ON FLTPLN. ANY TAPS REPORTS AHEAD?

04NOV1654PS 07993A
CMD
AN N176DZ/GL MCO1

1. QUATLDDDL.1DISPATCHER

** PLEASE ACK **
NO REPORTS THRU FL AND SOUTH..DL361 ATL-GCM INFNT OF U –ON SIMILAR RTE REPORTS SMTH OVR LAL FL350

TAPS Information Being Requested by Pilots, 11/9/05

At the urging of project personnel, this technical pilot inquired about TAPS during a trip.

.QXSXMXS 091443
A80
FI DL0596/AN N3760C
DT QXS ATL5 091443 M91A

1. 3401/09 KATL/KSJC .N3760C

ANY TAPS REPORTS ON OUR ROUTE AT 340? WE'RE STAYIN AT 340 4 WINDS ALL THE WAY. ANY BAD ALTITUDES IF OFFERED BY ATC?

09NOV1454GV 079A3A
CMD
AN N3760C/GL PDK5

1. QUATLDDDL.1DISPATCHER

** PLEASE ACK **
NEGATIVE TAPS
FL340 – AFFIRM – CHECK TIME/BURN AT BOTTOM OF PLAN FOR IDEA OTHER ALTS – AS YOU DESND INTO SJC – EXPECT TURB. NO OTHER REPORTS AT THIS TIME. BOTH HIGHER AND LOWER ALTS PROVIDED NO BETTER TIME/BURN.

.QXSXMXS 091458
A80
FI DL0596/AN N3760C

DT QXS ATL6 091458 M98A
1. 3401/09 KATL/KSJC .N3760C
THANKS. WE SAW FUELS SO JUST WANTED TO CHECK ON RIDES

09NOV1511GV 079A3A
CMD
AN N3760C/GL ATL6
1. QUATLDDDL.1DISPATCHER
** PLEASE ACK **
UNDERSTOOD – WHEN/IF I GET UPDATES I/LL PASS ALONG – THX

09NOV1518GV 079A3A
CMD
AN N3760C/GL ATL6
1. QUATLDDDL.1DISPATCHER
** PLEASE ACK **
THIS INFO JUST CAME THRU MY TRAFFIC –

OVR ERN CO-NE NM-NRN TX-WRN OK-WRN NB: LGT CHOP ASSOC MTN WAVE...CHOP AOB FL390

.QXSXMXS 091520
A80
FI DL0596/AN N3760C
DT QXS ATL6 091520 M04A
1. 3401/09 KATL/KSJC .N3760C
THNKS   WE-LL PLAN ON IT

09NOV1609PG 026A21
CMD
AN N3760C/GL LIT1
1. QUATLDDDL.1UPLINK.MSG
** NO ACK REQ **
AIRPORT ALERT – PSP SNA ONT LAX SJC SFO SMF OAK OMA
1544/09-0400/10 UPPERAIR 09NOV1544
MODERATE TURBC PSBL DURG CLIMB OUT/DESCENT BELOW FL120

.QXSXMXS 091615
A80
FI DL0596/AN N3760C
DT QXS LIT1 091615 M16A
1. 3401/09 KATL/KSJC .N3760C
PRETTY BAD RIDES AT 340 AND 360BETWN MEM AND LIT

.QXSXMXS 091616
A80

FI DL0596/AN N3760C
DT QXS MLU1 091616 M17A

1. 3401/09 KATL/KSJC .N3760C

DID WE SEND ANY TAPS DURING LAST 5 MINS? IF NOT THEN IT SHOULD

09NOV1621GV 079A3A
CMD
AN N3760C/GL MLU1

1. QUATLDDDL.1DISPATCHER

** PLEASE ACK **
COPY RIDES – THX. NO TAPS INFO SHOWING FOR ANYONE IN YOUR AREA.

.QXSXMXS 091631
A80
FI DL0596/AN N3760C
DT QXS TKI1 091631 M22A

1. 3401/09 KATL/KSJC .N3760C

THANKS. ILL TALK WITH THE TAPS GEEKS ABOUT THE SENSITIVITY

09NOV1635GV 079A3A
CMD
AN N3760C/GL TKI1

1. QUATLDDDL.1DISPATCHER

** PLEASE ACK **
TAPS GEEKS – FUNNY THAT YOU MENTION THAT. I JUST GOT OFF THE PHONE WITH ONE. HE DID MENTION THEY INITIALLY SET THE SENSITIVITY A BIT HIGH TO PRECLUDE EXCESSIVE REPORTS. HE SAID THEY ARE REVISITING THE SOFTWARE REPORTING WITH ADJUSTMENTS PROBABLY TO FOLLOW.

.QXSXMXS 091822
A80
FI DL0596/AN N3760C
DT QXS PGA1 091822 M32A

1. 3401/09 KATL/KSJC .N3760C

TAPS SHOULD HAVE SHOWN MOD CHOP AT 360 ABOUT 80NM SSW OF GJT
PLZ FWD TO TAPS GEEKS

09NOV1829GV 079A3A
CMD
AN N3760C/GL PGA1

1. QUATLDDDL.1DISPATCHER

** PLEASE ACK **
I/LL PASS THE WORD – NO DATA REPORTED FROM YOUR FLT.
Mr X IS THE /GEEK/ I SPOKE TO EARLIER. WILL SEND TO HIM.

.QXSXMXS 091832
A80
FI DL0596/AN N3760C
DT QXS PGA1 091832 M34A

1. 3401/09 KATL/KSJC .N3760C

HEE HEE .... THAT LAST PATCH OF TURBULENCE SHOULDDA DEFINITELY GENERATED A TAPS

09NOV1835GV 079A3A
CMD
AN N3760C/GL PGA1

1. QUATLDDDL.1DISPATCHER

** PLEASE ACK **
COPY THAT

09NOV1843GV 079A3A
CMD
AN N3760C/GL PGA1

1. QUATLDDDL.1DISPATCHER

** PLEASE ACK **
THIS FROM DELTA PROJECT PERSONNEL –

I SEE DL509 AHEAD OF HIM REPORTED WHAT THEYD PROBABLY CALL MODERATE TURB DESCENDING THROUGH 310 AND 300 EAST OF OAL.......

.QXSXMXS 091845
A80
FI DL0596/AN N3760C
DT QXS PGA1 091845 M38A

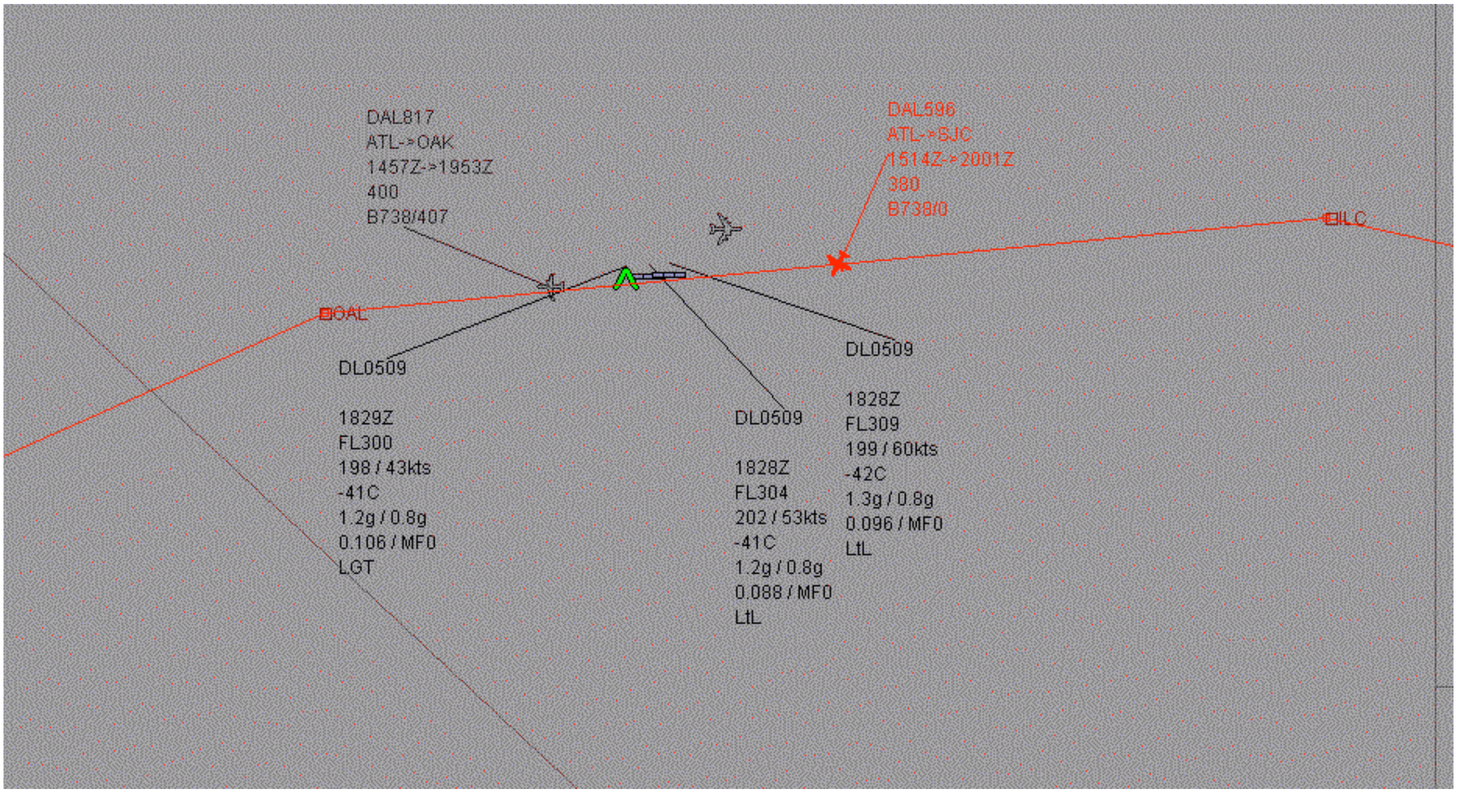
1. 3401/09 KATL/KSJC .N3760C

THANKS WE'LL SIT EM DOWN. TRULY THIS TAPS THANG IS GONNA B BENEFICIAL.

09NOV1855GV 079A3A
CMD
AN N3760C/GL LAS2

1. QUATLDDDL.1DISPATCHER

** PLEASE ACK **
BENEFICIAL – AGREED.



Follow-up Discussion RE: Above Scenario

From: Delta Project Personnel **Sent:** Mon 11/14/2005 2:10 PM
To: Delta Tech Pilot
Subject: FW: DFDR

FYI, to see if TAPS got it wrong or if you were just being a wimp, we pulled the DFDR from your flight X (ATL-SJC) on Wednesday. I'll let you know what we find out.

Thanks very much, though, for querying the dispatcher about TAPS, and please keep it up as able!!

-----Original Message-----
From: Tech Pilot
Sent: Tuesday, November 15, 2005 10:13 PM
To: Delta Turbulence Project personnel
Subject: RE: DFDR Ship 3760

Those "bumps" were significant enough that I would have definitely sat the Flight Attendants down unless they were in the middle of a major service. So, I guess the bumps we BAD but not (in retrospect) UNSAFE.... But, still bad enough that I would have sat the Flight Attendants down.

From: Delta Project personnel

To: Tech Pilot
Sent: Wed 11/16/2005 1:01 PM
Subject: RE: DFDR Ship 3760

Looking at the data, the first batch of turbulence between LIT and MEM looked like an rms g level of about .035, and the second batch (out west) was about .07. For context, the TAPS report threshold (which I admit is high) is .09. Anything between .2 and .3 is defined as moderate, and anything .3 or higher is severe+.

-----Original Message-----
From: Tech Pilot
Sent: Thursday, November 17, 2005 1:12 AM
To: Delta Turbulence Project Personnel
Subject: RE: DFDR Ship 3760

it is DEFINITELY set too low..... i will go so far as to say that you will need to lower the values to be success from an operational buy-in perspective.

TAPS threshold discussion – emails from Delta Meteorology, 11/18/05

-----Original Message-----
From:
Sent: Friday, November 18, 2005 9:09 AM
To: **Delta Turbulence Project personnel**
Subject: Taps?

Flight 37 today (LGW-CVG) is reporting moderate turbulence at FL320 on TRK B btwn 35-40W. TAPS is not picking up anything. Do you know if this is a TAP-equipped aircraft?

-----Original Message-----
From: Delta Turbulence Project personnel
Sent: Friday, November 18, 2005 9:30 AM
To: Delta Meteorology
Subject: RE: Taps?

It is a TAPS equipped aircraft, and looking at the MDCRS reports in Flight History, the turbulence they've been experiencing is just below the reporting threshold. The report at 1305Z (made at 59.4 N, 33.5 W), for example, tells me that the highest recorded rms g level over the previous 25 minutes was .077. The report at 1330Z (made at 59.6N, 38.6W), records the highest value as .078, while the one made at 1355Z (made at 60.1 N, 44 W – see below) has a value of .081. I see that the crew made their report at 1345Z.

Let me know if you have any questions, and thanks very much for the heads up! This kind of info. Really helps us make the case for refinements to TAPS.

QU ATLDDDL
.QXSXMXS 181345
A80
FI DL0037/AN N186DN
DT QXS UAK1 181345 M27A
1. 3401/18 EGKK/KCVG .N186DN
35W TO 40W CNT MOD CHP
OCNL MOD TURB
>|<
18NOV1355 000000

MDCRS report (covering the period from 1330Z to 1355Z):

QU ATLDDDL
.QXSXMXS 181355
DFD
FI DL0037/AN N186DN
DT QXS UAK1 181355 D66A
- 239N186DN0037181105135509785 6010 -4396350-24-51227 7902-234
62320
266 3950081 -634

-----Original Message-----
From: Delta Meteorology
Sent: Friday, November 18, 2005 9:35 AM
To: Delta Turbulence Project Personnel
Subject: RE: Taps?

We have to value to show set to .04, but it still hasn't shown up. Any ideas why?

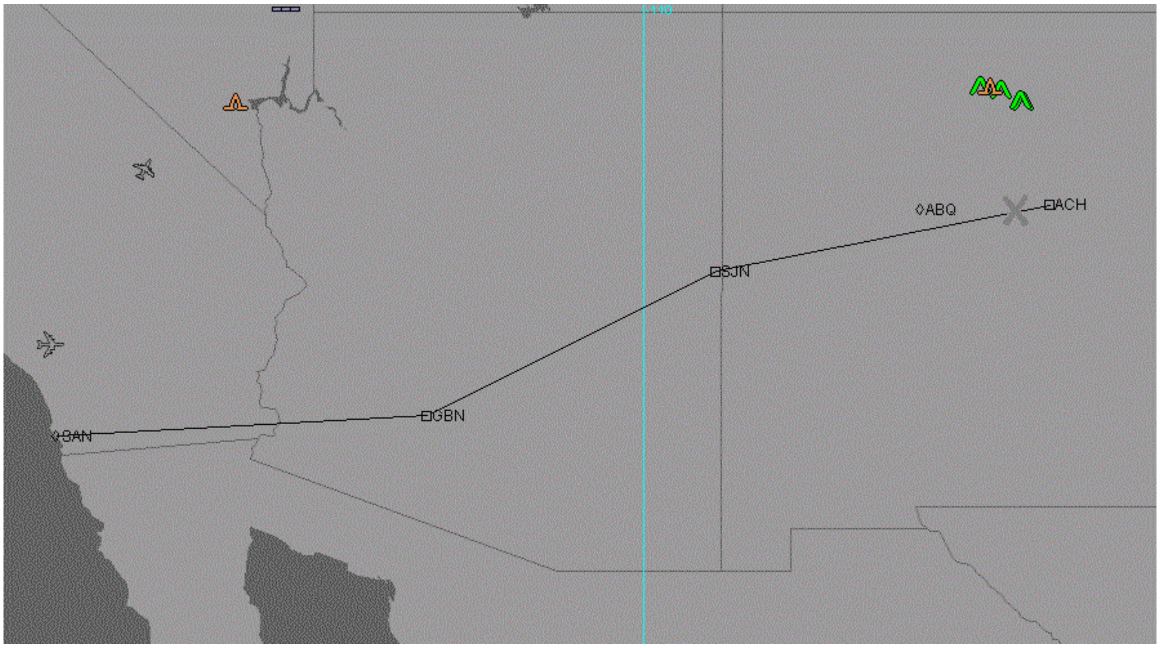
Reply:

That sliding scale is somewhat misleading based on the current TAPS report threshold. *On the aircraft*, in order for a report to be generated at all, it must be in the vicinity of .09-.1 rms g. So even if you slide the "minimum turbulence intensity" scale all the way down to 0, the only reports you'll really see will be about .09 or higher.

However, the 767-300Ers and 767-400s were coded so that the highest rms g level over the interval between each MDCRS report gets included in those MDCRS reports – whether that level is below or above the reporting threshold.

Looking ahead, the ideal solution would be to re-code the airplanes to generate reports about .04 and higher. This of course, has a cost associated with it, as lowering the report threshold increases the number of TAPS reports exponentially. In the meantime, I'd like to find a way to "map" the below threshold reports that get captured in those MDCRS reports. Thanks for the feedback in any case – I'll let you know developments/changes as they unfold.

TAPS Reports Near Report of Severe Turbulence, 12/2/05
Flight XXX, B767-200, ATL-SAN

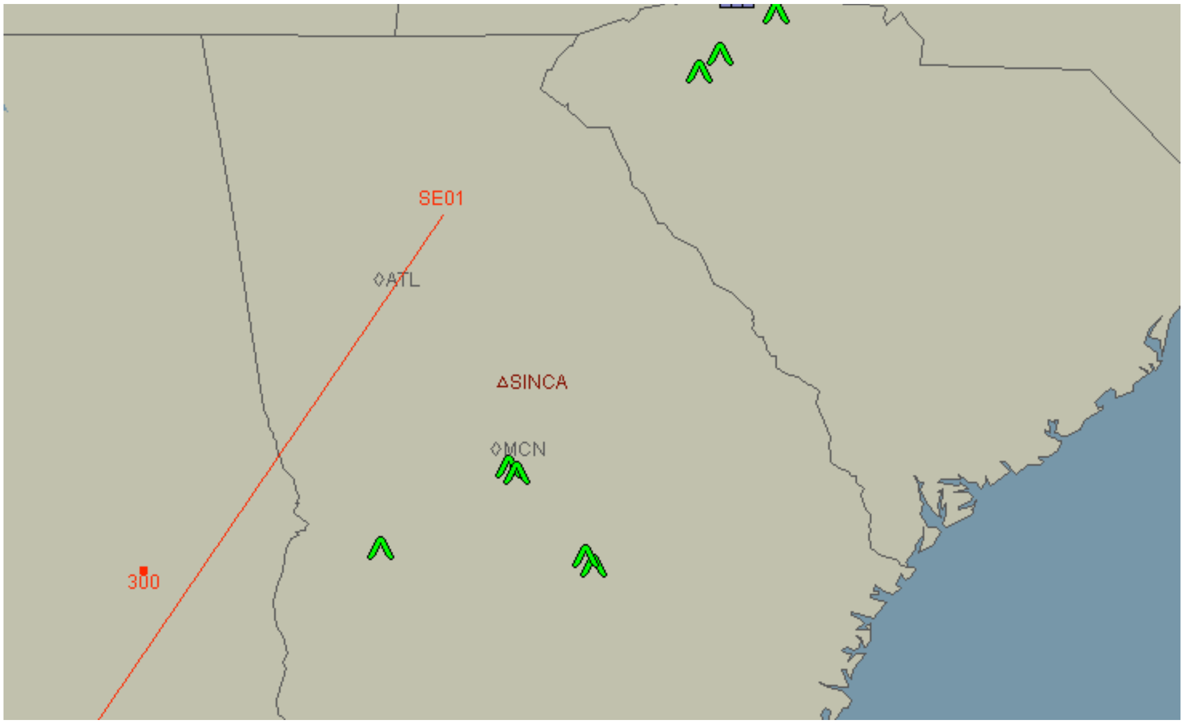


The "X" marks the spot of the "severe" encounter by flight 228, having occurred at FL330 and 1839Z. Nearby TAPS reports occurred at Flight Levels 340 and 370, between 1620Z and 1803Z.

Email from Dispatcher, 12/5/05

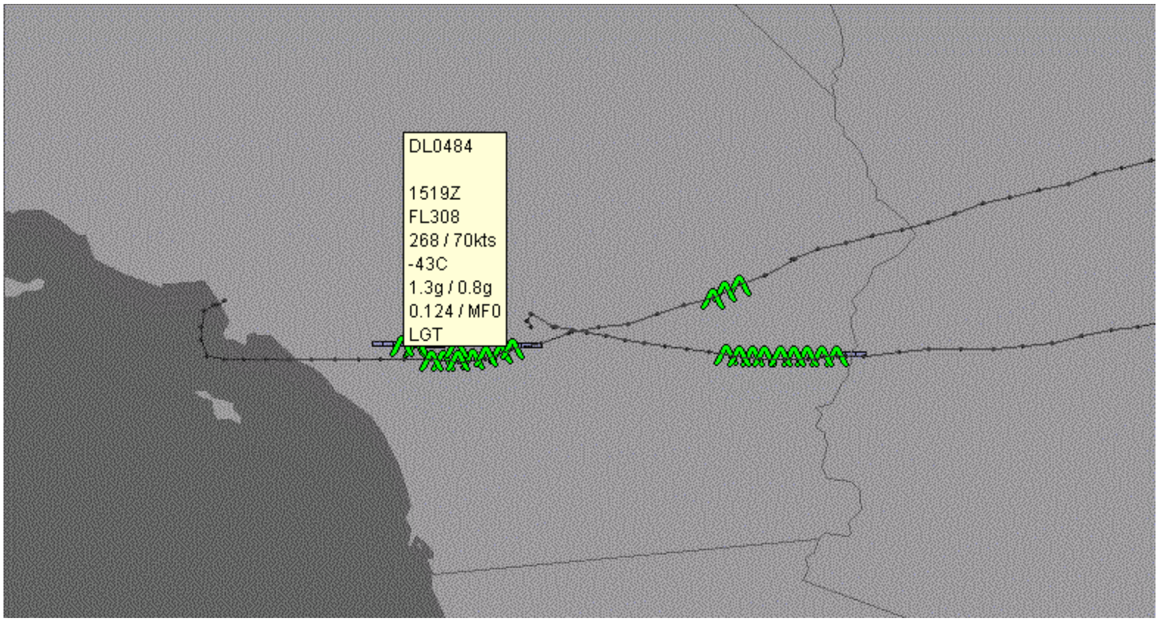
[Context: cold front sagging southeastwards through Atlanta]

FYI the system really helped me today giving very hard info to the pilots out of atl and down the east coast at the front passes.



Conversation with Dispatcher, 12/13/05

Headed down to dispatch to get dispatcher's feedback on (or bring to his attention) several reports sent by an aircraft he was handling (see WebASD snapshot below). He was not aware of the TAPS data, nor of the ACARS message from the crew regarding the turbulence (he scrolled through his messages very quickly, and ultimately I had to point out the crew's ACARS in his message queue). When asked if he referenced TAPS very much, he mentioned that he doesn't look at it very much (translation: never), because of limited TAPS equipage and limited overall usefulness. When I asked if the reports below would have been of help, he said that "Light-Moderate turbulence is an everyday part of flying," and therefore those reports had little value to him. When asked about what tools he *does* use for turbulence, he looks at Sigmets on ADDS, and pulls up conventional company PIREPs in his message queue. Overall, he was politely dismissive, and while his comments can be valuable, his lack of openness and contentment with current turbulence information is also not shared by the majority of dispatchers.



Conversation with Dispatcher, 12/13/05

Asked whether he looked at TAPS very much, dispatcher replied that he did not, mainly because of the extra step involved with pulling up WebASD. One strategy he uses to find turbulence while looking at GFF, for example, is to see what altitudes all aircraft are cruising at along specific routes (looking at all airlines), and using that to determine where the best ride is going to be. While he acknowledged that this approach certainly has its shortcomings, it's a display that he can look at to get a reasonable real-time picture of what guidance crews are getting on turbulence from ATC. If TAPS could be integrated into GFF, and if the reporting threshold could also be lowered to capture more bumps, that would make a huge difference in terms of its relevance to him.

Conversation with Dispatcher, 12/15/05

Asked whether he looked at WebASD very much, he replied with more of the same feedback as the dispatcher above (though was harsher in his criticism). Having dealt with numerous other ASD products, he thought WebASD was not intuitive at all and found it to be such a hassle he never looks at it. He traditionally references the ADDS page for conventional PIREPs, which is intuitive and "speaks his language." He did think TAPS had tremendous value, however, and feels it needs to be integrated into GFF.

Conversation with Dispatcher, 12/15/05

In defense of WebASD, dispatcher felt it was not terrible, and in fact, always has it running (at least minimized) during a shift. And while he agreed integrating TAPS into GFF would be the home-run solution, he also cautioned that even when integrated into GFF, not all dispatchers will choose to overlay the TAPS data. This is due to the fact that some dispatchers are more computer savvy than others, and he said not to be discouraged by this. To illustrate his point, he told a few dispatchers on the international desks about turbulence

that their flights were reporting (via TAPS) a few days ago, and said that the reception was basically indifferent because that group tends not to be as savvy as some others.

In applying TAPS, dispatcher has lately submitted reports of TAPS to the FAA database for display on the ADDS page (with no explicit reference to TAPS), and continues to circulate information from reports internally to give colleagues a heads up.

As for suggested improvements, dispatcher recommended that a legend explaining the rms levels and icons be available as a default overlay for those looking to better understand the TAPS information (for GFF and/or WebASD).

Email from Delta Meteorologist, with reply, 1/23/05

From: Metro
Sent: Mon 1/23/2006 4:51 PM
To: Delta Turbulence Project personnel
Subject: Taps question

I had a captain a while ago in the international training class that said the instruments that measure accelerometer data for TAPS is never or never has been calibrated. Is that true? What is the Quality Assurance methods for TAPS equipment?

I know some of our aircraft have bad temp/wind sensors because I get the report every month. The reports from these aircraft gets thrown out before going into weather models because they are unreliable, but that is from Forecast Systems Laboratory rather than Delta.

Reply:

Before I jump down his throat, I guess I'm not sure how the captain you spoke with meant his comments. The thresholds that we set initially (correlating rms g levels with Light, Moderate, and Severe as defined by the FAA/AIM and FOM) were based on many datasets collected from turbulence incidents and accidents, as well as from onboard a NASA 757 research aircraft in 2002. I was not aboard, but understand there were some very energetic moments circuiting convection across the southeast - so there were ample demonstrations of what rms levels meant in terms of cabin response in dialogue with the AIM. Still, as you know, we've discovered that our threshold for Light is probably high, given the fact that many pilots are reporting .1 rms as moderate. This year, we'd like to re-code the TAPS software to capture turbulence well below .1 and give you a much more comprehensive picture of what’s out there. Maybe he'd gotten info from a dispatcher telling him that some turbulence he'd encounter was only light according to TAPS, and was dissatisfied with that calibration.

This of course highlights the difficulty with all this, since everyone has a different opinion on what constitutes the right calibration. On the other hand, there is very good reason to trust the numbers coming from TAPS.

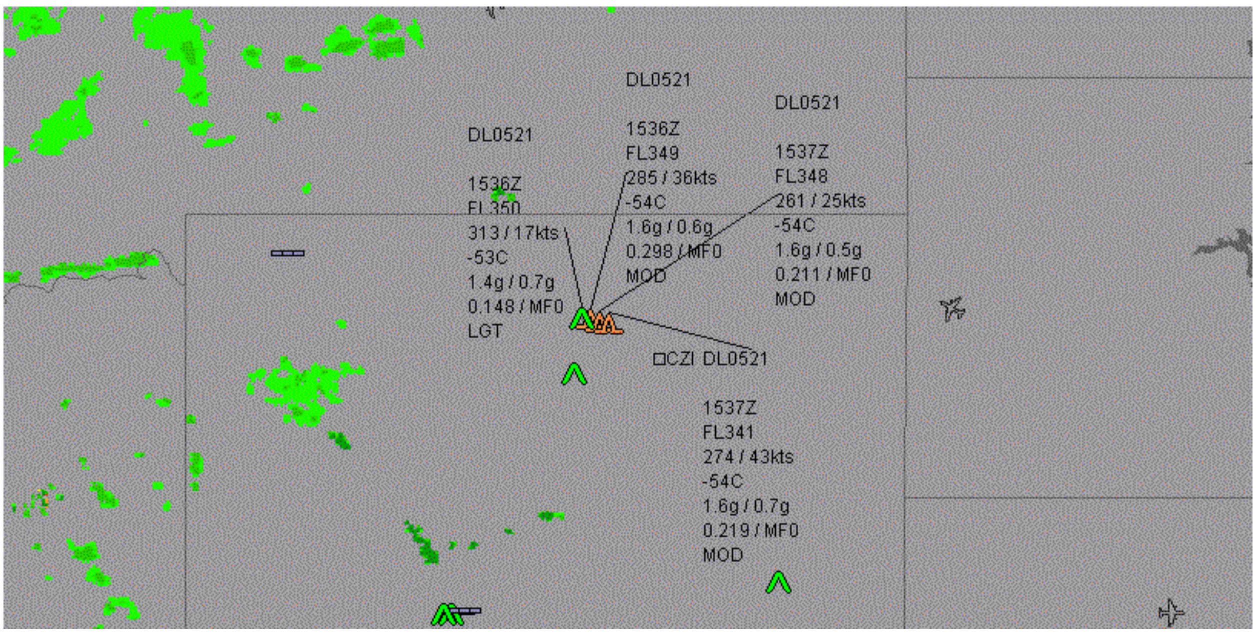
To validating the system’s performance, before outfitting all the 737-800s with TAPS, we conducted a very extensive month-long verification process with 1-2 airframes, comparing FOQA and DFDR data against TAPS. That process was repeated on the 763ERs and 767-400s prior to installation of the system on the rest of each fleet. Since then, we've continued to monitor that TAPS is doing what it should, as is necessary given the occasional databus and accelerometer issues that pop

up. Also, there are several filters which are in place on the ground to throw out any bad or suspect reports (due to the aforementioned databus or accelerometer issues). These issues get communicated to us and Tech Ops, and the bad reports do not appear on WebASD.

Sounds like this guy didn't have the whole picture, and maybe based an opinion on one encounter without getting all the facts?? I'm not surprised - I've found cynicism to be the scourge of the cockpit lately. Hope this clears this up in any case - if not or if you have any questions, please let me know.

DL 521, 1/11/06

During the morning, the project pilot noticed the following reports that had recently appeared on WebASD.



The ACARS history for this flight contained the following:

.QXSXMXS 111536
DFD
FI DL0521/AN N381DN
DT QXS BIL1 111536 D13A
- TRP 153509 44.2701 -107.1826 350 157.8 772 0.148 0.02099
17.0 -46.76 1.440 0.718 0.104 -0.119 -53 00 00 00 267 0

.QXSXMXS 111536
DFD
FI DL0521/AN N381DN
DT QXS CPR1 111536 D14A
- TRP 153539 44.2557 -107.0954 349 157.7 741 0.298 0.02236
36.0 -75.23 1.579 0.551 0.125 -0.143 -54 00 00 00 255 0

.QXSXMXS 111537
DFD
FI DL0521/AN N381DN
DT QXS BIL1 111537 D15A
- TRP 153609 44.2399 -107.0055 348 157.6 744 0.211 0.02212
24.5 -98.79 1.607 0.540 0.170 -0.266 -54 00 00 00 259 0

.QXSXMXS 111538
DFD
FI DL0521/AN N381DN
DT QXS CPR1 111538 D16A
- TRP 153639 44.2255 -106.9128 341 157.6 713 0.219 0.02287
43.0 -86.48 1.598 0.659 0.052 -0.137 -54 00 00 00 252 0

.QXSXMXS 111540
A80
FI DL0521/AN N381DN
DT QXS CPR1 111540 M29A
1. 3C03 0521/11 KPDX/KATL
/POS CZI /OVR 1539/NXT OVR /ETA 1639
/ENS BNA /ALT 330/FOB 0257/SAT 57
/WND 252063/MCH 77/TRB LT CHOP /SKY IN CLOUD /ICE NONE

.QXSXMXS 111543
A80
FI DL0521/AN N381DN
DT QXS CPR1 111543 M30A
1. 3401/11 KPDX/KATL .N381DN
FL 350 W OF CZI MOD TURB OCNL SEV CHOP. +/- 20KTS. 330 BETTER. PLZ PASS TO MTC. 10KT OVRSPD AND SVR TURB IN LOGBOOK.

11JAN1545DS 077116
CMD
AN N381DN/GL CPR1
1. QUATLDDDL.1DISPATCHER
** NO ACK REQ **
ACK. ANYONE HURT?

.QXSXMXS 111547
A80
FI DL0521/AN N381DN
DT QXS CPR1 111547 M32A
1. 3401/11 KPDX/KATL .N381DN
NOT YET. ASK AFTER LAWYERS ARE CALLED

The 737 Maintenance Coordinator then sent the following message:

11JAN1556PG 042212
CMD
AN N381DN/GL LBF1

1. QUATLDDDL.1UPLINK.MSG

** PLEASE ACK **
DISPATCH HAS REPORTED OVSPD AND SEVERE TURB. I NEED SOME SOME DETAILS TO DETERMINE TYPE OF INSP. OVSPD WITH FLAPS UP? NEED TO VERIFY TYPE OF TURB...SEVERE TURBULENCE IS IDENTIFIED AS TURBULENCE WHICH CAUSES LARGE ABRUPT CHANGES IN ALTITUDE AND/OR ATTITUDE. THE AIRPLANE COULD BE OUT OF CONTROL FOR A WHILE. IT USUALLY CAUSES LARGE VARIATIONS IN AIRSPEED. PASSENGERS AND CREW ARE MOVED VIOLENTLY AGAINST THEIR SEAT BELTS AND LOOSE OBJECTS WILL MOVE AROUND THE AIRPLANE. DID YOU HAVE SEVERE TURB?

A Radio Patch then occurred between captain, mx coordinator and dispatcher:

.ATLXGDL 111607
CJ 11:01:23 14 RAP
DL521 RQ PATCH DD92
ATL R SB
Captain:..SENT MSG ABT TURBC/REPLY FM MA WAS THAT WE HAD FL350 76 MACH WIND CLEAN AIRSPEED P/M 20KTS WENT INTO CLAKER ABT 4-7 TIMES DONT KNOW ABT ALT STARTED DSNDG AT 33
Mintenance:..WUD U SAY DEFINITION IS ACCURATE
Captain:..HATE TO DO IT BUT YES I DO
Maintenance:..HV SPECIFIC INSPECTNS FOR THAT TYPE OF TURBC WL GET THAT
READY
Captain:..SINCE DSND JUST LCP
Dispatcher:..***METRO SAID MTN WAVES FORMG AND U WERE ON LWR FRINGES OF THAT SO SHUD BE MUCH QUIETER REST OF FLT. DL..FL380 GUY WAS GETTING BEAT UP TOO.***
Dispatcher..***METRO SAYS AOB 350 IS BETTER BUT BASED ON U 33-34 IS MY LIMIT/U ARE PASSED ANY DANGER/CZI ANTICAPTG MTN WAVES***

The Maintenance coordinator then sent the following message:

11JAN1609PG 042212
CMD
AN N381DN/GL LBF1
- QUATLDDDL.1UPLINK.MSG
** PLEASE ACK **
I FORGOT TO ASK PER MAINTENANCE MANUAL DO YOU FEEL A
STRUCTURA

L INSP IS REQUIRED? PLZ INCLUDE IN YOUR IRREGULARITY. THX

.QXSXMXS 111615
A80
FI DL0521/AN N381DN
DT QXS LBF1 111615 M42A
1. 4303/11 KPDX/KATL .N381DN
/FRM / /
NO. I DON'T THINK ANY STRUCTURAL PROBLEMS

A structural inspection was therefore **not** ordered, and the aircraft continued on its rotation as normal.

On seeing this exchange, the project pilot went to the OCC to discuss the issue first with the dispatcher who handled the flight. Though he hates WebASD, he likes TAPS and was glad to have had the information available when it was presented at his desktop. He sent the following message to the crew:

CMD
AN N381DN/GL CPR1
1. QUATLDDDL.1DISPATCHER
** NO ACK REQ **
PER TAPS, YOUR ENCOUNTER WAS A HEAVY MODERATE. MAX LOAD WAS 1.6 G, MIN WAS .5 G. A HEALTHY BUMP BUT WELL WITHIN AIRFRAME LIMITS.

The project pilot then spoke with the 737 maintenance coordinator who also appreciated the information and included it in the daily TMC maintenance log (as below).

LOG INPUT 2017E 11JAN06 715913
3711 PDX-ATL G119891-001 MH-03.0 IMM- APU-
DLY 0521 01/11/06 0550 APU CYCLES-
IR-2017/11JAN/ATL/ 326900 – AT FL 350 ENCOUNTERED SEVERE
TURBULENCE WITH SUBSEQUENT OVERSPEED OF PLUS10 KNOTS
CLEAN CONFIG. DO NOT FEEL STRUCTURE PROBLEM OCCURED DUE
TO DURATION OF EVENT. AIRSPEED +/- 20 KNOTS BANK ANGLE
+/- 15 DEG.
CA-NO OVERSPEED INSP REQ PER MM 05-51-04. PER TAPS LOADS WERE
1.6 AND .5 WHICH ARE WITHIN LIMITS PER MM
NO STRUCTURAL INSP REQUIRED

Follow-up Emails between Project Pilot and Flight Safety personnel, 1/11/06:

FYI, in case you weren't aware of the severe turb event over Wyoming earlier today (I understand there were no injuries), here's what TAPS had to say on the matter.

All,

Attached is a snapshot of the turbulence DL521 experienced as captured by TAPS on WebASD. Though in the heavy moderate range, the worst loads experienced over the duration of the event

(which lasted about 2 minutes), were 1.6 g/.5 g, for a maximum deviation of just .6 g from 1 g. This is well below the flaps up airframe limitations of 2.5 g/-1 g.

Also attached is a text file containing the raw-format TAPS report in ACARS, with the maximum g load values highlighted.

Please feel free to be in touch with any questions, and thanks again.

Conversation with SLC-based line pilot
Jumpseat Observation, 1/24/06

Briefing the crew on TAPS, what the WebASD display looks like, the capabilities the system and the operational vision for it moving forward, Captain gave the following feedback. In the future, he'd prefer to see TAPS reports, scaled to his airplane, in a graphical format on either his nav display or on the dedicated radar/TCAS display (which sits in the center console on the 757 and 767). In terms of using TAPS information to drive operational decisions and create efficiencies, he was all for it, and said that his own threshold for changing altitudes is based on (1) whether or not a service is in progress, (2) what his altitude options are, and (3) what the fuel implications of an altitude change (up or down) might be. If there is no service underway, he prefers to sit everyone down, and drive through turbulence to avoid a fuel penalty.

For example, he recounted a flight 3 days ago during which there was turbulence east of SLC between FLs 280 and 390. His aircraft was at the flight planned altitude of FL360. He said that the airplane was still too heavy to make FL400, and going down to FL280 would have devastated fuel consumption. Since a service was not underway (and therefore there was no safety issue), he elected to remain AT FL360 and drove through about a hundred miles of light to occasional moderate turbulence.

Conversation with Sector Manager, 1/25/06

Sector Manager asked that I visit him to help prepare for an upcoming recurrent class that he'll be teaching in February. He had some basic questions about changing color preferences and saving those preferences for default views, etc. When I showed him how to change the colors of various overlays (satellite, Nexrad etc.), he suggested ARINC ensure that the mouse pointer turns into a thumb-like icon whenever it moves over the colors on the right side of the "Overlays" menu. He didn't realize that those colors could be changed by clicking on them, and felt that if the mouse was transformed into a thumb, then users could easily see that the color palette is a clickable, configurable item.

We ran into a number of issues when launching the display, including: lack of saved, default display settings, "Java out of Memory" errors, being prompted with various launch-associated windows that should only appear for first-time users etc. Each time WebASD started doing weird things, however, killing the browser and starting a fresh one did the trick.

DL503, 1/28/06

Captain reported severe turbulence at FL320 100 NM east of EKR. TAPS reports confirmed severe turbulence, but showed that the turbulence had actually occurred at FL340, and also did not indicate the need for a maintenance inspection.

Dispatcher shared this information (along with the picture below) with the dispatcher who handled the flight, but since the captain had already called it severe turbulence (and because the dispatcher who handled it apparently had no interest in dealing with the issue any further), a maintenance inspection was ordered upon arrival in SLC, and no structural anomalies were discovered. The aircraft was slated to overnight in SLC anyways, so no delay was incurred.

<u>Email from dispatcher to project personnel</u>

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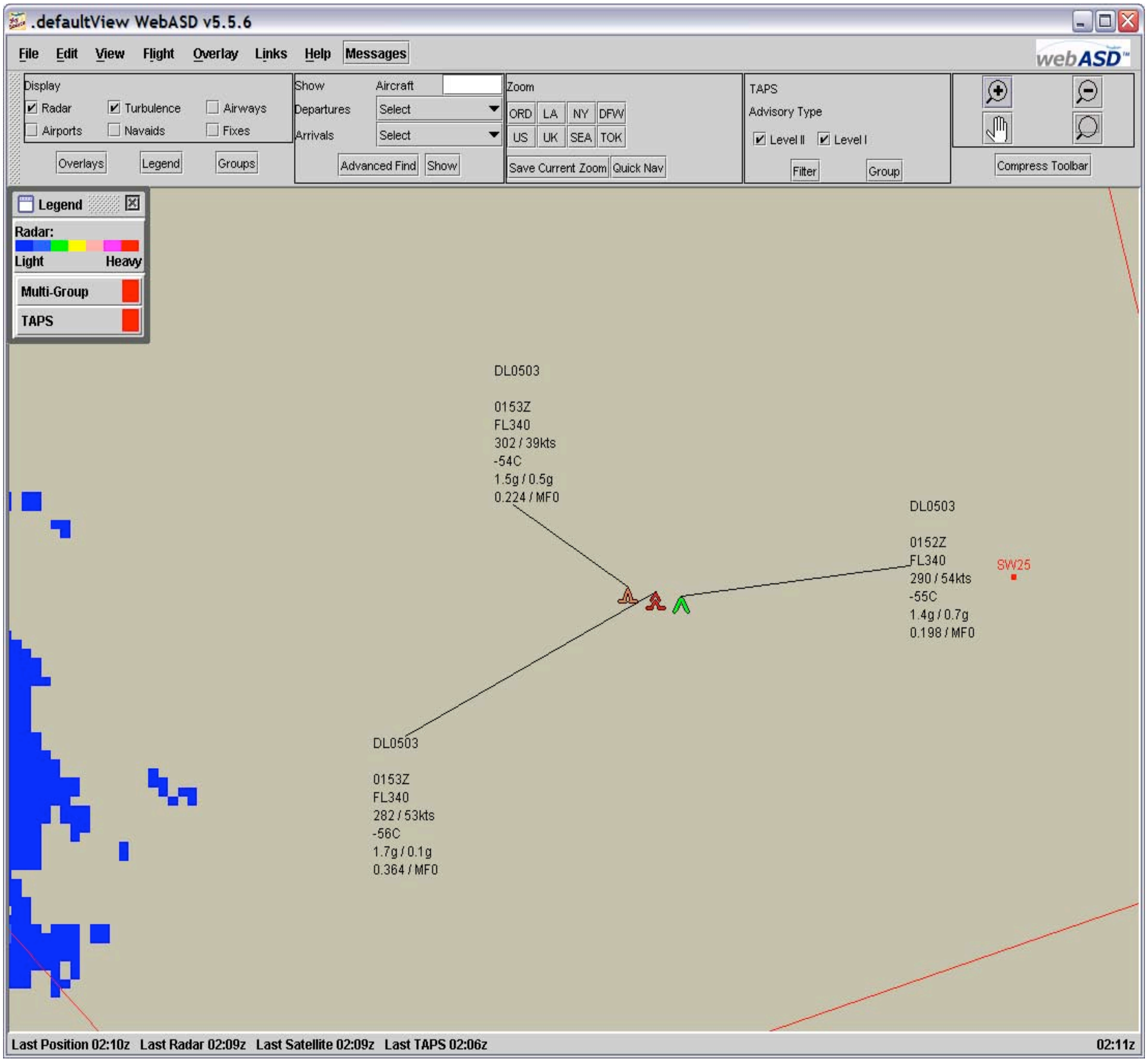
FI DL0503/AN N381DN
DT QXS HDN1 290154 D72A
-  TRP 015241  39.8222 -105.6857 340 145.4 755 0.224 0.02062
  38.5  -58.36  1.485  0.526  0.118 -0.084 -54 00 00 00 268 0
>P<
29JAN0153   000000

QU ATLDDDL
.QXSXMXS 290153
DFD
FI DL0503/AN N381DN
DT QXS EGE1 290153 D71A
-  TRP 015211  39.8138 -105.6130 340 145.5 751 0.364 0.02025
  52.5  -78.05  1.726  0.123  0.161 -0.180 -56 00 00 00 268 0
>P<
29JAN0152   000000

QU ATLDDDL
.QXSXMXS 290152
DFD
FI DL0503/AN N381DN
DT QXS EGE1 290152 D70A
-  TRP 015141  39.8048 -105.5477 340 145.6 756 0.198 0.01996
  53.5  -69.96  1.405  0.700  0.062 -0.088 -55 00 00 00 270 0
```



DL503/28 ACARS history:

(Immediately following the above TAPS reports)…

.QXSXMXS 290156
A80
FI DL0503/AN N381DN
DT QXS EGE1 290156 M89A
- 3401/28 KFLL/KSLC .N381DN
MOD/SEV TURB 100 NM E OF EKR AT 320

.QXSXMXS 290205
A80

FI DL0503/AN N381DN
DT QXS HDN1 290205 M92A
- 4303/28 KFLL/KSLC .N381DN
/FRM / /
MOD/SEV TURB AT FL 340 FOR 30-60 SECS. NO ZIPR [Overspeed] ENTRY. THX.

29JAN0206PG 035734
CMD
AN N381DN/GL HDN1
- QUATLDDDL.1UPLINK.MSG
** NO ACK REQ **
RCVD YOUR MESSAGE
NAME: XXX TITLE: B737 MTC COORDINATOR

29JAN0208BS 076F2B
CMD
AN N381DN/GL HDN1
- QUATLDDDL.1DISPATCHER
** PLEASE ACK **

ACK TURBC REPORT. . . PLZ CLARIFY SEVERITY. . .SEV OR MOD. ALSO ARE THERE ANY ONBOARD INJURIES - PSGRS/CREW? IS THE ACFT OK TO CONTINUE? MAY I OFFER ANY ASSISTANCE?

.QXSXMXS 290212
A80
FI DL0503/AN N381DN
DT QXS HDN1 290212 M96A
- 3401/28 KFLL/KSLC .N381DN
+ - 30 KNOTS/+ - 1500 FPM. IT WAS SEVERE/NO INJURIES/A/C SEEMS FINE

29JAN0214BS 077031
CMD
AN N381DN/GL HDN1
- QUATLDDDL.1DISPATCHER
** PLEASE ACK **

ACK. . .TURBC THX. I HAVE PSGR SERVICE MEETING YOU. WAS THE SEAT BELT LIGHT ON AND WERE THE F/AS SEATED?

.QXSXMXS 290217
A80
FI DL0503/AN N381DN
DT QXS GJT1 290217 M98A
- 3401/28 KFLL/KSLC .N381DN
YES AND 1 FLT. WAS UP. CAPT MADE PA 10 MINS PRIOR FOR ALL TO BE

SEATED. EVERYBODY OK

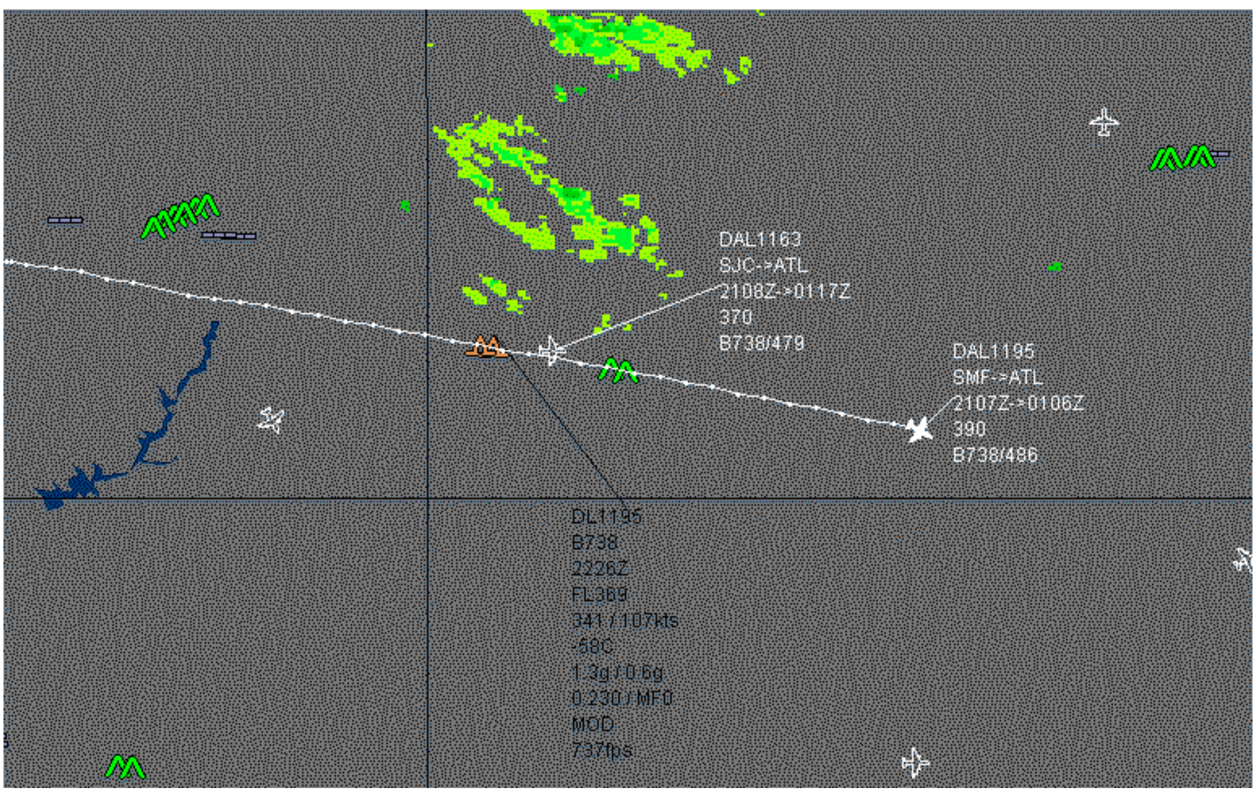
29JAN0218BS 079A16
CMD
AN N381DN/GL GJT1
- QUATLDDDL.1DISPATCHER
** NO ACK REQ **

ACK. . . THX - MTC AND PSGR HDLG MEETING YOU IN SLC FOR ASSIST.

WebASD snapshot, 1/29/06

Notice the 2 moderate TAPS reports from DAL 1195, made at FL370 just ahead of DAL 1163. Just 8-10 minutes after these reports were made (and as pictured here), DAL 1163 transited the very same piece of airspace as the location of the reports, but no TAPS reports were made. Inspection of the ACARS history for flight 1163 revealed regular reporting of "DFD" type MDCRS reports, so it appears that the "box" was functioning properly.

Problems related to the validity reports, it seems, extend far beyond the realm of just convective turbulence. This example serves as a cautionary tale in applying even very good information in the ways that have been conceived for TAPS during the cruise phase of flight so far.



Appendix D

Delta Air Lines' Flight Crew Feedback on Multiscan/E-Turb Radar

The following catalogues all qualitative feedback concerning the performance of the Multiscan radar, and subsequently the combined performance of the Multiscan and E-Turb magenta for all entries after 8/21/04. Each entry represents feedback captured via (1) hard copy questionnaires that were available on the flight deck and mailed to project personnel, (2) phone conversations with pilots who used the radar during encounters with convective weather, (3) detailed observations by project personnel occupying the jumpseat, and (4) information regarding system performance that was sent via ACARS for review by project personnel.

Note: Jumpseat observations were also conducted between October of 2006 and January of 2007, but no E-Turb magenta or significant weather was encountered.

Date	Source	Feedback
5/25/04	Email from line pilot to B737-800 fleet captain	"Flew 3708 (Multiscan ship) a couple nights ago from SFO to JFK around significant wx in the mid-west; it was night time and the radar was needed. I was very impressed by the multi-scan capability. It lived up to the billing – much better than the normal 737NG radar! A definite safety benefit in the information presented and ability to analyze returns."
Various	According to 737-800 Technical Manager, Anecdotal information from various line pilots	All positive feedback, no negative reviews of any kind
5/16/04	Jumpseat observation, flight 570, SLC-IAD Conditions: encountered several cells over the Midwest, did not enter IMC at any point while deviating	1. Both pilots were very pleased with the Multiscan's automated capabilities 2. Weaving between cells, the captain remarked that he did not "buy" a particularly sharp gradient in reflectivity within one echo. 3. Pilots were impressed by the much better defined magenta available in WX+T mode compared with other radar units. In this case, magenta was painted only within the most reflective portion of the cells

6/23/04	Jumpseat observation, flight 523 ATL-SFO, flight 670 SFO-ATL Conditions: encountered a few isolated cells enroute, deviation not necessary at any time	1. Positive comments about system capabilities and special features 2. On climbout from SFO, in auto mode, first officer remarked that he saw exactly what he wanted to see on the radar screen given some small buildups east of the Sierra Nevada mountains 3. First officer remarked that the gain control had better credibility than previous systems. On other units, changing the gain did not always result in the echoes showing proportionally more or less reflectivity 4. Painted magenta in areas of little or no reflectivity near Atlanta (but did not transit areas) 5. Even though a few small, distant cells were present enroute, overall basis for evaluation was disappointing due to scanter than expected convection around Atlanta
7/5/04	E-mail from line pilot to 737-800 Fleet Captain	I used the new radar and liked what I saw under the conditions that I used it on. I came back to ATL on a day with a lot of cells in the area and the auto feature was great. When I was above developing cells that were close by the radar would never over scan them and when I descended below the bottoms of some of the cells it did a nice job of showing me, even though I was below them, where they where located. I have clearly defined cells displayed that matched what was outside.
6/14/04	Crew Operations Report (COR)	I used the new radar going to CCS. It is extremely sensitive and displayed even minor weather has heavy. Had we not switched back and forth between traditional settings and the new self scan, we would have deviated a long way around weather that was either well below us or minor. Perhaps if we had more information it would be a better tool. Overall it is too sensitive (just my opinion).
6/30/04	COR, **Flight number** XYZ **Location** JAX **Reference number** XXXX **Time** 1500Z **Actual city pair flown** ATL-RDU **Ship**	First leg with AC3708 with new test radar. We were deviating for wx in JAX center airspace on freq 127.87. Jax directed us to go direct to a fix on the RDU arrival. We were painting a strong isolated cell on the requested course and stated we could not accept that routing. JAX then directed 15 degrees left for traffic. The cell was too close to this turn and we said we were unable to comply. The controlled then became agitated and asked us if we were using our emergency authority to contradict an ATC directive. I replied with an affirmative response. We were able to take his original requested course within 10 to 15 miles after passing the cell. A contributing factor was this radar with auto tilt. It tends to tilt lower and paint a lot more wx than I normally see at cruise. After switching to manual tilt with a 0 tilt angle, the strong cell almost disappeared from our

	number 003708 **Aircraft type** 737-800 **Crewmember** X **Employee number** X **Base** ATL **Crewmember Category** B737 CAPT **Category** Aircraft **Condition Safety concern?** Yes	display. **(See Follow-up conversation with captain, 8/17/04, below)**
7/29/04	Jumpseat dialogue with 737-800 crews, flights 467 (ATL-DFW), 381 (DFW-SAN)	Scott Smith (ATL based F.O.) said that the WXR700 (conventional unit on 737NGs) tends to be too sensitive. Often, it will paint red in a certain spot, and when crews have to penetrate the area they find only light-moderate precipitation. Interestingly, and in contrast to some other feedback received on the Multiscan, he said he did not encounter this problem during either of the two flights that he was aboard ship 3708 with the Multiscan radar installed. To him, it showed a much more realistic picture than the previous radar. Important unknowns in this kind of feedback are the gain settings that were used on both the Multiscan unit and the conventional WXR700 radar. During previous jumpseat rides, I noticed the gain setting on the Multiscan unit spun to its highest level of sensitivity, particularly at higher altitudes. Awareness of the Multiscan's automatic gain feature, which automatically compensates for reduced reflectivity at higher altitudes and colder temperatures, may be lacking. Further emphasis on setting the gain to "CAL" and leaving it there may be needed. This potential variation in gain settings may be a leading cause of the kind of anecdotal feedback regarding radar sensitivity currently being received.
8/17/04	Follow-up conversation from COR dated 6/30 (issue deviating with JAX center)	When asked where the gain was set during the event mentioned in the COR, the captain stated that it was at CAL in auto mode, where it remained when put in manual mode. Tom Staigle and Christian Amaral cited the automatic gain, as well as OverFlight protection features as factors in the reduced reflectivity that resulted when the radar was placed back in manual mode. The captain further stated that as soon as he denied the controller's clearance by exercising his emergency authority, the controller asked other Delta aircraft (presumably transiting the area that the radar had predicted as hazardous, though there's no way to be certain) for ride reports. All aircraft responded that the ride was smooth, and after about one minute of deviating, the captain accepted direct to the fix where he'd previously been asked to proceed. When asked if the aircraft penetrated the area where the radar had painted high

		reflectivity, the captain responded that they skirted the edge of that area but did not penetrate the “core.” Christian and Tom explained that his issue underscores a broader, more fundamental change in terms of what the new radar is communicating versus previous radars. That is, raw returns are being replaced by hazard assessments, and the E-Turb will enhance that effect even more. Assessing the particular situation with which the captain was confronted, the other Delta aircraft that were in the vicinity of the cell could have been just above (or just past) something that was about to give them a very rough ride, as predicted by the Multiscan. Since the captain deviated, we’ll never know. Also, conditions were IMC, so there was no way to visually verify the top of the cell in question. The other possibility, of course, is that perhaps the radar is too sensitive, as has occurred in the past with the introduction of GPWS and TCAS systems.
8/21/04	Jumpseat observation, flight 1062, DFW-ATL	While in AUTO mode with the gain set to CAL, a cell with strong echoes was detected ahead and to the left of the flight path. At the time, the aircraft was in IMC at FL330. Taking the radar out of AUTO mode and leaving the gain at the same setting, the cell nearly disappeared, showing green and a hint of yellow with the tilt at 0 degrees, -1 and then -2. The cell essentially blended in with other light echoes all around. Cranking the gain to the highest setting was required to display the same reflectivity as in AUTO mode at that altitude, and the captain remarked that he normally would leave the gain alone (at the calibrated setting) on the previous radar, adjusting the tilt downward to detect the hazard instead. Again, operating the radar in this fashion yielded very benign echoes, and both pilots remarked that, without the advisory information provided by the Multiscan's automatic functionality, they would have had no reservations about transiting the area where the radar had painted nasty weather while in AUTO mode. We weren't really certain what to make of the system at this point, wondering whether the unit was in fact too sensitive. ATC then issued a clearance to FL410, at which time we popped out on top of the cirrus. At the same time, the top of the echo that the Multiscan had detected as hazardous became visible, ending in an anvil at about FL430 or 440.
8/23/04	E-mail from Captain to project pilot	I had the opportunity to use the new wx radar on 18 Aug from LAX-SLC on flt 252. The new wx radar is a big improvement over the older radar system on the 800 fleet. The auto-tilt feature significantly reduces crew workload in a convective weather environment and the wx display is much more accurate in terms of where the actual cells are located and what degree of convective activity they contain. The new radar provided the crew with very accurate wx/turb information minimizing the disruption to cabin service and the chance for turbulence related injuries to the crew and pax. It's a great system and I hope when economic conditions improve, this system can be retrofitted on the remainder of the 800 fleet.
8/25/04	COR (based on a flight earlier that day from DFW-ATL)	**Paraphrased from actual COR**: Liked the Multiscan radar, and felt it did an excellent job of distinguishing cells at long range. Very dissatisfied with the turbulence feature, however, which did not show the continuous light chop that was experienced in cumuliform clouds at mid-altitudes (15,000-25,000 feet). Turbulence was painted in cells, but that should be fairly obvious. Did not feel that the feature was of any value, since the turbulence was painted only where one would expect to find it, and did not correlate with the light turbulence that was experienced. **Supplementary data:** Even though TAPS software had been installed on this

<table>
<tr><td></td><td></td><td>aircraft on 8/24, there were no TAPS reports associated with this flight. The account above may be corroborated by events 7, 8, 9, 10 and 11 on the 8_26_04.evt file from the data logger.</td></tr>
<tr><td>8/31/04</td><td>Jumpseat observation, flight from ATL-PHL</td><td>Even though very little weather reflectivity appeared during the flight, magenta was painted in one area near Atlanta while it was not present in a cumuliform cloud that the pilot felt would be turbulent. Upon entering the cloud in question, the turbulence was relatively smooth.</td></tr>
<tr><td>9/16/04</td><td>Jumpseat observation, flight 340, COS-ATL (Hurricane Ivan)</td><td>Context: Rome Arrival into Atlanta, lots of convection and turbulence associated with the northeast quadrant of Hurricane Ivan. An unprecedented number of TAPS reports on this arrival, with several moderates as the day progressed (including one moderate from ship 3708 on flight 954, ATL-LGA). A request for ride reports yielded “moderate turbulence all the way in until turning final.”

Multiscan Performance: The Multiscan automated functionality worked flawlessly throughout, significantly reducing pilot workload in some very challenging airspace.

E-Turb Performance: Descending from 27,000 to 23,000 feet, speckled (but sparsely distributed) magenta began being depicted in areas of very low and nil reflectivity. When we transited the area, the bumps were very, very light, not unlike turbulence we had been encountering for some time in similar IMC conditions. Because of building weather over ERLIN intersection, ATC then vectored us 20 degrees left of course, which brought us directly into an area of more concentrated speckles. Recognizing this, the first officer asked for 20 degrees right of course as an alternative, which would have taken us very close to the heavier reflectivity at ERLIN but avoided turbulence (since there was none predicted in that area). ATC denied the request, and there was good correlation between the speckles and what we experienced. A glance at the altimeter during this encounter read 19,300 feet (in the course of a descent).

During the remainder of the descent, which included a few minutes in VMC between layers, very little if any magenta was depicted. Throughout this period, the flight crew and I felt that the turbulence experienced was just as intense as the area where concentrated speckles had been displayed previously.

Additionally, ATC advised traffic on frequency of a microburst 1 mile to the northeast of runways 8L and 8R (on the north side of the field). A speck of magenta was apparent in this vicinity while on final.

Supplementary data: 2 TAPS reports during this segment, both in the light range.

9/16/04 340 15:19:12 34.2183 -85.3631 0.134
9/16/04 340 15:27:12 34.0611 -84.8313 0.107</td></tr>
<tr><td>9/24/04</td><td>Jumpseat observation, flight 446, JFK-SAN</td><td>Observed isolated cells, separated primarily by VMC conditions, at altitude. The captain remarked that the Multiscan did an outstanding job of painting the cells as they actually appeared, including the overhang typical of thunderstorm tops. Using the previous radar, this overhang went virtually undetected.

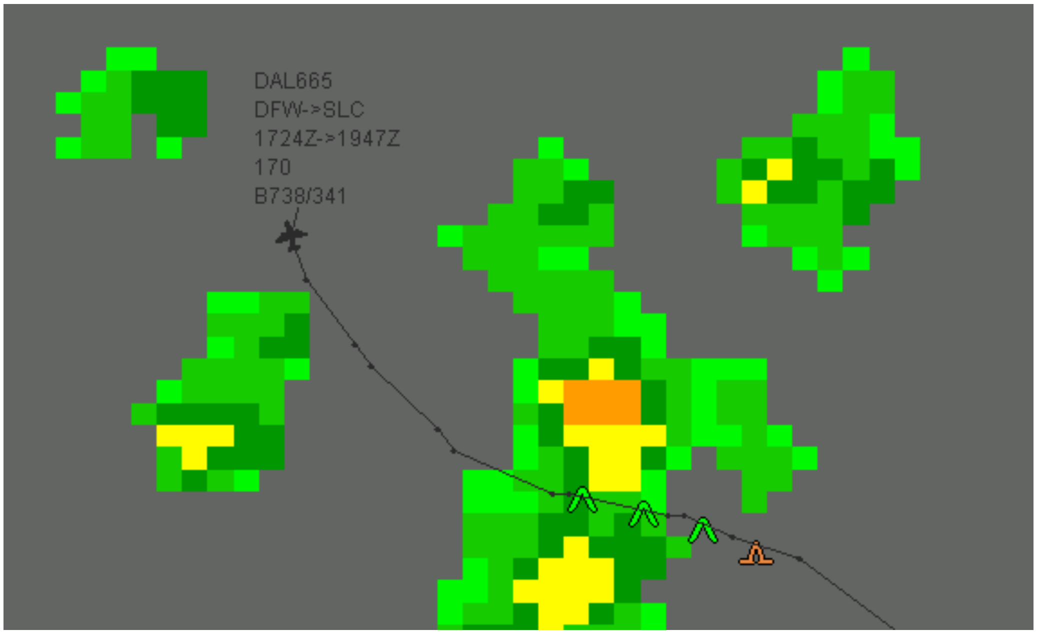
Even though the aircraft path was within 25 nautical miles of the storms, no magenta was depicted within these cells.</td></tr>
</table>

		Also, both pilots had flown ship 3708 previously, and were very impressed with the Multiscan's capabilities. The captain mentioned a flight in August from LAX to GDL (Guadalajara, Mexico) during which the new system was especially helpful. While descending into GDL, the crew's workload was significantly reduced thanks to the cancellation of ground returns in the vicinity of thunderstorms and mountainous terrain. However, the captain also mentioned a flight during which strong returns were painted even though the tops were well below the altitude of the aircraft. He recounted that the aircraft was cruising at about FL350, and estimated that the cell tops in question were at approximately FL200, 80-100 nautical miles distant. Even though the cells were this far from the aircraft, he confidently asserted that the cells topped out well below the aircraft altitude.
9/25/04	Jumpseat observation, flight 788, SAN-ATL	Observed isolated cells over New Mexico and the Texas panhandle. Both pilots had flown ship 3708 previously, and saw the system as a very significant improvement vs. the previous radar. Even though the aircraft path was within 25 nautical miles of the storms, no magenta was depicted within these cells.
10/18/04	Jumpseat observation, flight 1169, PHX-CVG-LGA	Leg 1: PHX-CVG **Context:** Lots of rain with embedded convection ahead of a cold front pushing through the Ohio Valley throughout the day. Indianapolis Center had descended every CVG arrival from the west very early due to airspace restrictions associated with the weather. TARNE3 arrival to runway 18R, solid IMC all the way to about 800 feet. **Multiscan Performance:** Excellent **E-Turb Performance:** Patch of speckled magenta encountered at FL290 within an area of relatively low reflectivity (green), and all felt that the correlation between the turbulence predicted by the magenta and the turbulence actually experienced was very good. At first, the captain commented that perhaps this area had been a false warning, since the magenta began to disappear behind us while the ride remained smooth. Before he could finish this sentence, the bumps occurred. Also had good correlation between a patch of speckled magenta encountered just after leveling at FL230, and skirted the right side of an area of concentrated speckles to the east and north of TARNE intersection. Similar turbulence encountered in areas where speckles were very sparsely distributed (from about 10,000 to 5000 feet, and particularly around 9,000 feet). This may have merely been turbulence just below the threshold established for the speckled magenta, but such experiences can be confusing and may underscore the need for significant education on the system once it is deployed more widely. Leg 2: CVG-LGA Relatively smooth with just a few speckles of magenta depicted during the climbout. Otherwise smooth, and no significant weather to LGA.

10/18/04	Jumpseat observation, flight 323, LGA-CVG	**Context:** After a modified holding pattern at Henderson VORTAC (HNN) due to a line of storms over the CVG airport, vectored to the north, then west, then south for a landing on 18L. Storms containing the highest reflectivity had largely moved south and east before being cleared from HNN, but lots of rain and turbulence still remained for the arrival. **Multiscan Performance:** Excellent **E-Turb Performance:** From 11,400 feet until about 9,000 feet, an area of predicted turbulence (concentrated speckles) within relatively low reflectivity correlated very well against what was experienced. Initially, the low reflectivity (green and nil returns) made both pilots skeptical about the existence of the turbulence, but after transiting the area, they agreed that the magenta had in fact told the truth. For the remainder of the descent, sparsely distributed speckles appeared within areas of relatively higher reflectivity (yellows), and the turbulence was fairly smooth.
11/23/04	ACARS from pilot, flight 1236, ATL-MCI	QU ATLDDDL .DDLXCXA 231838 A80 FI DL1236/AN N378DA DT DDL MCI 231838 M27A 3A02/23 KATL/KMCI .N378DA MDT TURB ENCOUNTERED DP RTG ATL THRU 9000. NO MAGENTA DSPLY. ENROUTE FL310 MDT CHP NO DSPLY SEVRL RANGES.SEND 2 737 FLET **Supplementary Data:** No relevant TAPS reports
12/6/04	Anonymous response to hard copy of onboard E-Turb Questionnaire	1. Were you satisfied with the presentation/design of the 2 levels of magenta (if applicable)? - **Yes** a. If not, what did you see as deficient (e.g. definition around the 2 levels etc.)? **Only dispersed pattern displayed** 2. Did the aircraft penetrate any area(s) where magenta was indicated? **Yes!** a. If so, did you feel that the magenta accurately predicted the level of turbulence experienced (if any)? **Turb was present and approached moderate** 3. Was the 25 NM range of the magenta adequate for avoidance and/or the crew's ability to secure the cabin? **More notice would be better. By the time we were able to coordinate, we were in it.** 4. Did you encounter turbulence within clouds in areas where no magenta was depicted? **N/A**

		a. If so, would you have liked to have seen that turbulence depicted or was it too light to be worthwhile? Please feel free to include any other feedback in the space below. **Great to have had the little warning we did!**
3/22/05	ACARS response to request for feedback from project pilot, flight 1555, ATL-FLL	**Context:** Ideal proving ground for E-Turb, with lots of convection throughout south Georgia along the route of flight. Several TAPS reports (included below with rms g levels highlighted) were made during climbout and cruise. **MESSAGE FROM DISPATCHER (prior to departure):** ** PLEASE ACK ** WHEN ABLE PLEASE SEND FEEDBACK ON PERFORMANCE OF NEW RADAR, PARTICULARLY PRESENCE/ABSENCE OF MAGENTA WITH WX/T MODE SELECTED **TAPS REPORTS:** - TRP 192452 33.4561 -84.1313 139 145.7 513 0.119 0.03715 73.5 -139.57 1.295 0.716 0.087 -0.031 -6 00 00 00 245 0 - TRP 193952 32.4275 -82.7580 360 142.1 777 0.104 0.01985 75.5 -119.53 1.387 0.803 0.049 -0.039 -42 00 00 00 257 0 - TRP 194052 32.3492 -82.6357 359 142.0 806 0.176 0.01880 74.0 -127.97 1.304 0.595 0.113 -0.042 -36 00 00 00 264 0 - TRP 194352 32.0245 -82.4414 360 141.7 796 0.085 0.01899 90.5 -121.29 1.252 0.812 0.067 -0.047 -30 00 00 00 257 0 - TRP 194422 31.9634 -82.4133 360 141.6 796 0.099 0.01866 91.0 -123.40 1.176 0.819 0.066 -0.039 -32 00 00 00 259 0 - TRP 194452 31.9064 -82.3837 360 141.6 799 0.112 0.01852 87.5 -124.45 1.321 0.844 0.093 -0.044 -33 00 00 00 261 0 - TRP 194522 31.8507 -82.3535 366 141.6 800 0.098 0.01848 90.5 -125.51 1.321 0.776 0.066 -0.038 -32 00 00 00 255 0 - TRP 194722 31.6300 -82.2444 380 141.2 765 0.087 0.01976 106.0 -121.99 1.165 0.739 0.057 -0.056 -31 00 00 00 236 0 **CREW FEEDBACK:** A80 FI DL1555/AN N378DA GOT GOOD WORKOUT WITH NEW RADAR. MAGENTA TBC WORKED GREAT

<table>
<tr><td></td><td></td><td>EVEN AT HI ALT WITH MIN MOISTURE</td></tr>
<tr><td>4/17/05</td><td>ACARS message from crew, flight 1630, ATL-SLC</td><td>FROM RZC [waypoint in northwest Arkansas] TO PER [waypoint in north central Oklahoma], IN AND OUT OF CIRRUS WITH INTER LT CHOP. E TURB RADAR NOT PAINTING ANYTHING</td></tr>
<tr><td>5/5/05</td><td>Conversation between project pilot and captain, flight 665, DFW-SLC</td><td>Descending into SLC, in the vicinity of convection, the aircraft sent a string of TAPS reports, including one moderate report.



After landing, the captain commented that he was very pleased with the E-Turb system's performance, which he said painted only speckled magenta. In his opinion, that correlated very well with what he experienced as turbulence "approaching moderate."

Additionally, he noted that the radar issued windshear alerts during taxi-in, and the tower confirmed the presence of microbursts south of the field.

TAPS Report data:

- TRP 192753 40.1047 -111.4755 189 123.4 574 0.200 0.02676
27.0 -171.21 1.467 0.657 0.066 -0.058 -18 00 00 00 254 0

- TRP 192823 40.1228 -111.5312 189 123.4 554 0.185 0.02709
30.0 -170.51 1.433 0.563 0.090 -0.067 -17 00 00 00 245 0

- TRP 192853 40.1346 -111.5909 190 123.4 566 0.186 0.02752
26.0 171.21 1.300 0.455 0.108 -0.120 -18 00 00 00 250 0</td></tr>
</table>

		- TRP 192923 40.1461 -111.6527 186 123.3 553 0.111 0.02749 32.0 165.59 1.366 0.863 0.060 -0.041 -17 00 00 00 245 0 - TRP 193223 40.3185 -111.9246 169 123.2 557 0.154 0.02822 28.5 -161.37 1.398 0.718 0.094 -0.046 -13 00 00 00 254 0 - TRP 193323 40.3981 -111.9864 166 123.2 541 0.103 0.02811 26.5 -172.97 1.243 0.746 0.034 -0.015 -13 00 00 00 251 0 - TRP 193453 40.5272 -112.0554 149 123.1 478 0.132 0.03055 29.0 -170.86 1.279 0.712 0.083 -0.029 -8 00 00 00 224 0 - TRP 193853 40.8204 -112.0849 107 122.9 401 0.136 0.04023 21.0 -161.72 1.314 0.709 0.047 -0.037 1 00 00 01 202 0
5/12/05	Jumpseat observation, flight 505, ATL-DEN	Lots of convective activity associated with frontal system over the US mid-section. East of Memphis, while level at FL380, passed between 2 cells in clear air. Speckled magenta overlaid red reflectivity in cell to the right (north of route). No turbulence encountered. NOTE: While in Memphis Center's airspace, numerous aircraft asked if it would be possible to cut out some waypoints along their flight plan routes, since the weather system presented numerous options for tactical deviations. The response from ATC was, "There are weather routes from the Northeast into the West and Southwest, and we have been told to grant no shortcuts without first calling traffic management." Near the Oklahoma panhandle/Colorado/Kansas borders, while level at FL360, heading 290 in cirrus cloud, a speck of magenta ahead and to the left of the flight path, associated with a small circle of green reflectivity, appeared. The captain turned on the seatbelt sign. The magenta then disappeared, and the area of reflectivity also began to dissipate. Moments later, the aircraft emerged from the cirrus, revealing a small buildup that topped out just below the altitude of the aircraft. No turbulence encountered.
5/13/05	Jumpseat observation, Flight 1022, SLC-EWR	Continued convective activity associated with frontal system over US mid-section. During taxi-out, ground control advised the crew to call clearance delivery for a re-route to the filed flight plan. Clearance confirmed that the re-route was due to weather over the mid-section of the US, and issued a drastic re-route to the north. Instead of a more or less linear due east routing to Newark (in accordance with the original flight plan), the re-route drew an arc whose top was at the upper peninsula of Michigan, adding 200 NM to the journey and resulting in an arrival that was 30 minutes late even though the flight departed on-time. Arrival time would have been later had the captain been less conscientious about looking for the best winds and asking for shortcuts. Even though the range of the radar extended to 320 nautical miles, weather was painted only once. The cells captured were 150-200 NM distant, had lots of space between them, and were just to the north of Detroit.

7/15/05	Jumpseat observation, Flight 1419, ATL-MSY	Lots of convection throughout the eastern U.S. associated with a low pressure system that had come ashore the prior weekend as Hurricane Cindy. All descriptions assume AUTO mode with the gain set to calibrated. Climbing away from Atlanta at about 4500', ATC issued a vector due to weather over JCKTS intersection. This weather was depicted on the radar screen in green and yellow, and even though the aircraft was within about 15 NM of the cell, there was no magenta associated with it. Due to weather west and southwest of MEI (Meridian, MS), numerous deviations were made enroute. During descent at FL250 in IMC conditions, a few specks of magenta associated with a small patch of green reflectivity appeared ahead. Though the ride was relatively smooth in surrounding areas, only very light chop was encountered while transiting this area. Later, while descending at FL180 and again in IMC, more specks of magenta, associated with black (nil) returns, appeared in the flight path. As the aircraft approached the area where the specks had been apparent, however, magenta disappeared. Lots of reflectivity with speckled and solid magenta appeared to the right of course during the remainder of the descent into MSY. Due to a late descent from ATC, however, a left hand 360 degree turn was made. Magenta was not apparent in any cells during the turn, but reappeared a few seconds after rolling out and resuming the arrival towards runway 19. No areas of magenta or reflectivity were penetrated for remainder of the flight.
7/15/05	Jumpseat observation, Flight 871, MSY-HSV-ATL	Upon contacting departure immediately after takeoff from runway 19, ATC issued a right hand vector to 320 degrees. Reflectivity there was green and yellow, though nil to the left. The captain requested a left hand turn to the same heading instead, and the controller denied the request citing traffic to the east and reports of a smooth ride from 2 Southwest B737s that had departed through the area of weather just before. In addition, no magenta was depicted in that area, and as advertised, a smooth ride was experienced. Because of widespread thunderstorms across Mississippi, Alabama and Georgia, an ATC reroute prior to takeoff had put the flight on an enroute heading of due north towards Memphis before a right turn towards the ERLIN2 arrival into ATL. Heading 010 towards Memphis, weather was depicted at fairly long range in a northeasterly line from Jackson to Columbus, MS. The captain requested to cut the corner towards ERLIN in order to take advantage of a large hole north of the line, but was denied due to "in-trail flow restrictions" from the Traffic Management Unit. In the first officer's estimation, this routing added about 250 NM to the flight, and the FMS calculated an additional 30 minutes to Atlanta. All was rendered moot, however, when a lingering thunderstorm over the Atlanta airport and holding at 2 locations progressively closer to the arrival necessitated a 2.5 hour diversion to Hunstville, AL. Continuing from HSV to ATL, no significant weather close to the flight path was encountered. The top of a small cumulus buildup with no reflectivity and no magenta, however, was encountered in VMC during cruise at FL190. The captain nonetheless elected to deviate around the cloud with a quick left turn before returning to the flight plan route, and asked why he had not seen any magenta. I responded that the turbulence in the cloud probably amounted only to light chop that was below the

		magenta trigger, but couldn't be sure since we didn't actually go through the cloud.
7/29/05	Jumpseat observation, Flight 890, CVG-TPA	Lots of convection south of the TN/GA line, associated with a stationary front draped across the southeast. While deviating left of a cell over Atlanta, windshear was forcing the temporary closure of the Atlanta airport. Thunderstorms extended through south Georgia into the Florida panhandle around Tallahassee, then quieted before picking up again along the west coast of the peninsula. The captain, who remarked that he was relatively new on the 737-800, was the pilot flying. First cells encountered were east of Chattanooga, TN, extending south over Atlanta while at FL370. Green and yellow returns were observed with the radar in AUTO mode, and the captain deviated well left and clear. In marginal IMC conditions between Chattanooga and Atlanta, however, no magenta was observed while flying through an area of nil reflectivity, and the ride was in fact smooth. Several more cells, showing lots of red, dotted the route south of Atlanta towards Tallahassee. The captain chose a narrow passage that avoided all reflectivity. South of Columbus, GA, the captain took the radar out of AUTO mode, demonstrating how he would normally use the conventional radar. Leaving the gain at the calibrated position and tilting at 0 and -1 degrees, reflectivity was, of course, significantly reduced, and he felt that he was getting more reflectivity in AUTO mode than was actually present. I then explained the automatic gain compensation, and after pointing out the cells as they appeared through the windows, both crewmembers somewhat grudgingly agreed that the picture painted by AUTO mode had indeed told the truth. While green returns in AUTO mode mostly represented the edge of storms, prompting deviation, only black had been present in the same areas while in manual mode. From the standpoint of an effort to validate the magenta by getting into *some* IMC conditions, the reluctance to penetrate any reflectivity was frustrating. I wished that, in good conscience, I could have dialed down the gain while in AUTO mode to achieve better validation. Still, we did get well within 25 nautical miles of many cells showing heavy reflectivity, and, interestingly, very little magenta was observed in and around these areas. One might speculate that these storms were diminishing due to the onset of nightfall. During the descent towards Tampa, a more or less continuous line of cells was observed left of course. While level at FL240, magenta speckles appeared in green reflectivity but left of course, 15 NM distant. Magenta was observed ahead, again left of course, descending through 15,000 feet. For no apparent reason, the captain took the radar out of AUTO mode at 8000 feet, even though no cells and VMC conditions prevailed for the remainder of the flight. Once on the ground, I asked the captain why he had taken the radar out of AUTO mode, and he explained that due to the high workload, his newness on the 737-800, and the presence of thunderstorms in the vicinity, his behavior almost subconsciously defaulted to the familiar. I told him I understood, but also explained – as humbly as possible – that by eliminating workload to help the crew focus on flying the airplane, that's exactly the environment in which the automation shines. Though the Multiscan picture definitely appears more accurate than the one painted by previous generation systems, as pilots *currently conceive* using the weather radar in

		the en route environment, it is scaring crews to deviate much wider from storms than they might otherwise. Meanwhile, in the terminal area, where reflectivity for the same gain setting on older systems is naturally much higher, crews are used to seeing a lot of red on the radar screen. During this flight in fact, the first officer remarked that he often sees a lot of red during the approach phase of flight, only to discover heavy rain and a fairly smooth ride. So due to the wide disparities in the picture given by a constant gain setting on legacy systems, areas of high reflectivity at low levels appear to be of much lesser concern than red returns at altitude. With training and experience on newer radar systems, perceptions and methodologies about reflectivity and hazard are likely to change, but getting to that point will be a challenge for those used to older systems.
8/23/05	Jumpseat observation Flight 385, ATL-MCI	The pilot turned the radar on while taxiing out to the runway. Since he had flown the plane before, he was very comfortable with just leaving the tilt alone and keeping the gain in Calibrated. We hit all of our waypoints and climbed to FL340. There was no weather to speak of (just a few very small patches of green) until we approached Memphis. Dave's navigation display clearly showed that there was a fairly large storm cell directly in the flight plan outbound from Memphis (we were about 120 nm away when we saw it). [Aside: the majority of the time the pilots has the radar set in the 80 nm range setting and even smaller when operating around convection. They only went out to 160 and 320 for quick looks at the area]. As we got closer the cell showed yellows and greens. From the outside view, it appeared that the tops went up to FL370 or higher. The pilots asked for a deviation around the cell and it was approved by ATC. As we maneuvered around the cell, I didn't see any turbulence magenta in that particular cell, but we did encounter some of what I would consider less-than-light turbulence. We got around that cell and continued on the flight plan to Kansas City. We were assigned the Tyger 5 Arrival for an intercept to ILS for RWY 1R. As we neared Kansas City we could see clouds at the lower altitudes in between us and MCI (Kansas City). As we descended on the approach we picked up some greens on the radar and experienced some minimal turbulence. As we got closer to the ILS we could see heavier green cell near the BARBQ waypoint and some speckled magenta (about 5 nm to the left at 5,000 ft. We never encountered anything that I would call light turbulence. We did encounter rain on the ILS without any green on the radar. The landing was uneventful. Concerning Turbulence information in the cockpit, both wanted safety of flight information before ride quality. Dave thought that the E-Turb feature was a huge plus when operating in the Southeast and especially Florida where Delta flies some flights that are so short you can't really do any deviation. It's great to know the turbulence when you have to pick your way through the storms. Both liked the idea of getting

		automatic turbulence reports that would come up on their nav display as long as they could be turned off to reduce clutter if needed.
8/23/05	Jumpseat observation Flight 262, MCI-ATL	We were given the Lakes Four departure to St. Louis. As we were climbing out past the Napoleon NAVAID, Dave asked for direct to St. Louis. The controller came back with go direct to Nashville. So the pilots selected Nashville as the next way point in the Nav computer. I asked them if they needed to tell the dispatcher that they got direct to Nashville and they said "No." Dave asked about any altitude reports and the controller came back with one report of light chop about 50 miles to the north. We did have some choppy turbulence at FL370 enroute, but really no significant weather until we got closer to Georgia. We were given the Rome Two arrival. About 40 miles to the east of Nashville we started to pick up some nasty looking cells around the Rome NAVAID and ERLIN waypoint. As we got closer, we could here planes starting to deviate around the cells. Approach control asked us come right to deviate around the weather. Both Dave and Ralph really were using the radar to look at the reflectivity and the turbulence (none yet). We were cleared down to descend to 13,000 ft. We crossed through the first storm line about 24,000 ft. See WebASD picture below. The storm cells were red in the middle and contained a lot of speckled magenta on the edges. The Multiscan helped us to find a hole between the tops of two cells (hole seemed clear down to 20,000 or so, Cells tops were 35,000+ on one and around 30,000 on the other). The pilots did deviate a couple degrees off of the Approach issued heading to get into the holes. The TCAS icons showed all of the aircraft picking their way around the cells. We could here some aircraft trying to shoot the holes at lower altitudes. They kept asking for deviations due to weather (turbulence?). As 3708 rounded the cell, Approach brought us back to the left to intersect the DALAS waypoint and get back on the Rome 2 arrival. There were large weather cells out our left window the rest of the way in (lots of yellow and red). I did see some speckled magenta, but never any solid magenta (centers of the cells were > 25 nm away). We did have some clouds layers that didn't even paint green on the radar as we came in past the DALAS waypoint at around 13,000 ft. We did have a little turbulence as we continued in for the ILS, but nothing significant. The landing was uneventful. Dave thought it would be nice if the radar could be programmed to know when to turn itself on and off. That way the radar was totally automatic and he didn't have to worry about anything other than interpreting the data.

8/30/05	Jumpseat observation Flight 814, ATL-RDU	Near the eastern portions of the remnants of Katrina, there were still some showers in the area from a feeder band passing through the region. On takeoff the radar was in Wx+T mode and pointed up +5°. As we took the runway, the radar showed a green and yellow cell over the runway and on climbout. No magenta was displayed. We experienced heavy rain on the take-off roll and took off into the cell. It was bumpy – but less than the 0.09g threshold. I don't believe the radar should have indicated anything. On climbout a green/yellow cell to the right of the flight path showed some solid magenta around its perimeter. As we turned left in the climb we broke out of the cloud layer at about 8,000ft. ATC had us crossing a line of convection. Our flight path was to take us through a build up showing 4 - 5 solid magenta regions at the edges with green and yellow regions inside. ATC assured us it was a smooth ride. The pilot requested a deviation left of the cell. There was no significant weather for the remainder of the flight.
8/30/05	Jumpseat observation, Flight 1555, RDU-ATL	There was a ground hold for Atlanta (wx I think) and we took off about 15 minutes late. Standard Takeoff from RDU – no wx in the area and we climbed to FL280. Nearing ATL we passed by a couple of cells that had heights of about 33,000ft. The radar showed green with yellow in the middle, and several solid magenta "blobs" around the edges. We began our descent. We passed by – still in VMC. The Nexrad image being captured by ATR personnel showed us in a red region – maybe it was below us, but there was nothing where we were. Another clear example of how the NEXRAD composite map is not a useful or reliable tool (on its own) for flight decisions. On descent into ATL we passed through a layer of clouds between 8,000ft and 5,000ft. There was some very low intensity turbulence. The pilots asked me why it didn't show up on the radar. Another education issue – not all clouds show up on radar. It depends on their water content. There was no signal from this cloud layer (as perceived by the radar). Below the clouds the ride was bumpy (light – maybe).
9/30/05, 10/1/05	Observation by Tech Pilot and F/O aboard 3708, flight 451	After arranging for ship 3708 to be the aircraft for rotation to UVF (St Lucia) and back, pilot flew 3708 and had the following comments. Encountered several cells offshore of Florida's east coast and over the Caribbean, and both he and the captain were very impressed with the Multiscan's automatic functionality. It gave them exactly the picture they

	(ATL-UVF), flight 1296 (UVF-ATL)	needed with no workload required. F/O tried to be somewhat aggressive and convince the captain to transit some areas of green reflectivity, ultimately to no avail. Additionally, the presence of magenta was depicted in the vicinity of reflectivity on the display, but none was transited. While flying at FL390, however, in minimally reflective cirrus blow-off (no returns on the nav display), a rough ride was experienced in the absence of magenta. Pilot felt that he should have seen some speckled magenta in this area. However, the circumstances surrounding this encounter (high altitude, no green depicted on the display, in very light cirrus cloud) probably indicate a level of reflectivity below the threshold necessary for any turbulence to be captured by the system. Pilot took a picture of the cloud in which the encounter occurred (below). The Cb top in the middle was not transited - merely the surrounding cirrus.

Glossary

ACARS – Addressing Communications and Reporting System, used to provide aircraft-ground and ground-aircraft text datalink using the VHF radio

ADDS – Aviation Digital Data Service, a web-based product maintained by the FAA Aviation Weather Center

AIM – Airman's Information Manual, published by the FAA as a reference for pilots and dispatchers regarding procedures for aircraft operations

AIRMET – As used in this document, an official advisory issued to aviators due to the potential for moderate turbulence in an area of defined dimensions

AOC – Airline Operations Center, usually housing dispatch and meteorology departments

ARINC – Aeronautical Radio Incorporated

ATC – Air Traffic Control

ATIS – Automated Terminal Information Service, updated information broadcast to aviators regarding weather conditions and any important Notices to Airmen at a given airport

CAT – Clear Air Turbulence

CIWS – Corridor Integrated Weather System, a set of weather products aimed at reducing the impact of convection on the management of air traffic in high density areas such as the Northeast

EDR – Eddy Dissipation Rate

E-Turb – Enhanced turbulence prediction mode for airborne weather radar

FAA – Federal Aviation Administration

F/O – First Officer, or co-pilot, on the flight deck

G – One unit of acceleration of gravity at 9.8 m/sec^2

GFF – Graphical Flight Following, a tool designed by Delta Air Lines for use by Delta dispatchers in the real-time monitoring flights. GFF interfaces with a variety of other applications, including flight planning.

GTG – Graphical Turbulence Guidance, a forecast product available via the FAA's ADDS Aviation Weather Center

ICAO – International Civil Aviation Organization

IPT – Integrated Product Team, a working group element of the Joint Planning and Development Office

In-situ – associated with reference to measurements made at the actual location of the object or material measured, as opposed remote sensing (e.g., from space)

ITWS – Integrated Terminal Weather Service, a product that fuses together the FAA and National Weather Service (NWS) weather sensors in the airport terminal area to provide automated weather forecasts

JPDO – Joint Planning Development Office

MSL – Mean Sea Level, height above sea level corrected for non-standard atmospheric pressure

NAS – National Airspace System

NASA – National Aeronautics and Space Administration

NCAR – National Center for Atmospheric Research

Nexrad – Ground-based, composite Doppler weather radar

NGATS – Next Generation Air Traffic System

OCC – Operations Control Center at Delta Air Lines, housing dispatch, meteorology, maintenance control, and other operational planning groups

PIREPS – Pilot Reports (normally of weather conditions encountered aloft)

PWS – Predictive Windshear, a capability built into most modern airborne weather radars, PWS warns crews about hazardous windshear occurring close to the ground

Rms g – Root Mean Square of a Gravitational force on a body for a given time interval

SIGMET – As used in this document, an official advisory issued to aviators due to the potential for severe turbulence in an area of defined dimensions

TAPS – Turbulence Auto PIREP System

TCAS – Traffic Collision and Avoidance System, a system that uses data broadcast by aircraft transponders to aid in preventing traffic conflicts. On most modern airliners, nearby aircraft are presented as TCAS “targets” on a cockpit display, and pilots can view the data to see the path that aircraft ahead of them may be taking in real-time. This information is often used as guidance in avoiding hazards in areas of widespread thunderstorm activity.

TPAWS – Turbulence Predication and Warning Systems Project

WebASD – As referenced in this report, a web based flight following display provided by ARINC as a platform for displaying TAPS reports

Wx – Abbreviation for “Weather”

WxAP – Weather Accident Prevent Project

WXR-2100 – Rockwell Collins Multiscan airborne weather radar

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14. ABSTRACT
Concluding an in-service evaluation of two new turbulence detection technologies developed in the Turbulence Prediction and Warning Systems (TPAWS) element of the NASA Aviation Safety and Security Program's Weather Accident Prevention Project (WxAP), this report documents Delta's experience working with the technologies, feedback gained from pilots and dispatchers concerning current turbulence techniques and procedures, and Delta's recommendations regarding directions for further efforts by the research community. Technologies evaluated included an automatic airborne turbulence encounter reporting technology called the Turbulence Auto PIREP System (TAPS), and a significant enhancement to the ability of modern airborne weather radars to predict and display turbulence of operational significance, called E-Turb radar.

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